

THE
LIVING GARDEN

or The How & Why of Garden Life

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PREFACE

THIS BOOK is partly the outcome of the importunities of my friends, but mainly of a hope that it may engender a greater interest in the plants amongst which the garden lover dwells. If it is my good fortune to succeed in stimulating a more vivid appreciation of plants as living entities, it is perhaps not too much to hope that I shall have done something towards a closer co-operation between the professional botanist on the one hand, and the horticulturist on the other.

It is unfortunately true that most botanists know all too little about horticulture, whilst the majority of those keenly interested in gardening have but a meagre acquaintance with advances in botanical knowledge. Each obtains an insight into the growth and functions of the living plant that would be helpful to the other. Those who possess gardens have unrivalled opportunities for observing living plants at all seasons, under the most varied conditions, such as are often denied to the scientist, and their observations could be of inestimable value in supplementing the exact experiments of the trained investigator.

One would like to envisage a future in which the great majority of horticultural enthusiasts are a band of voluntary helpers in our pursuit of the knowledge of plants. It is mainly in the hope of doing something to promote this ideal that these chapters have been written. In such an attempt, I may be said to be following a great tradition. For the first of my distinguished predecessors in the Quain Chair of Botany at University College was John Lindley, who for nearly forty years was Secretary of the Royal Horticultural Society, edited the *Gardener's Chronicle* for nearly a quarter of a century, and was mainly responsible for saving Kew Gardens for the nation.

I have here tried to present the plant as a living organism in relation to its garden home, interpreted in the light of the most recent research, but so far as possible without recourse to technicalities.

The value of technical terms is that they convey a precision of meaning which is sometimes impossible when familiar words and terms are alone employed, but such precision of meaning is only attained when the reader has been trained to appreciate their precise significance. To the layman the technical term may be just unintelligible jargon, or it may be actually misleading by association with a different mind-picture to that which its technical sense is meant to convey. Therefore, in attempting to present various aspects of plant life in a non-technical garb, I hope that I shall not be accused of the unforgivable sin of 'talking down' to my readers, but that the presentation will be accepted as an honest endeavour to avoid both technicalities and misconceptions. Those of my readers whose technical knowledge would justify the use of scientific terminology will no doubt condone the circumlocution which a non-technical presentation sometimes involves. But if technicalities are avoided, it is essential that the reader should give the same attention to the value of the words used as one is forced to give to technical phraseology.

This is in no sense a text-book, although the results of investigations and investigators too numerous to mention have been drawn upon in its preparation. The various chapters present certain aspects only of garden life from the point of view of one interested in plants as they are influenced by and influence their conditions of growth. If our knowledge of plants is a reality and not a mere mass of information, it should do for us what Shelley said of poetry—'Lift the veil from the hidden beauty of the world.'

I should like to take this opportunity of expressing my indebtedness to Mrs. G. M. Caroe, who is responsible for a large proportion of the illustrations, and for her co-operation and interest in their preparation, to the Publishers for the care they have expended on the production of the book, and to my wife and to Professor J. R. Matthews for assistance in reading the proofs and for a number of helpful suggestions.

E. J. S.

University College
London, 1935

PREFACE TO SECOND EDITION

ONE outcome of this war, as of the last, is that many thousands, who previously had scarcely handled a plant, have discovered the practice of horticulture to be a means of re-creation of both mind and body. Many more have realised, for the first time, the very real contribution that horticulture can make to both the necessities and amenities of life.

In times of peace the novice can often achieve some measure of success by following blindly the formulæ of practice built up on the experience of trials and errors of past generations, but, for professional and amateur alike, the present circumstances impose changes in practice that may necessitate readjustments throughout the entire system of culture. So it becomes more than ever desirable to apprehend the processes of nature and to understand the basis on which our practices rest.

It is therefore hoped that the present Edition will make available to a wider public this attempt to provide such a background.

I should like to express my gratitude for the very generous appreciations from practical Horticulturalists and fellow Scientists which welcomed the first Edition, and not least for the many letters in which correspondents, both at home and abroad, have enriched my knowledge by informing me of their observations and experience.

No fundamental changes have been made in the text, but the opportunity has been taken to correct misprints and minor errors, for calling my attention to which I am indebted in several instances to correspondents.

E. J. S.

Willow Pool
Radlett
Herts
October 1941

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CHAPTER I

WHAT IS A GARDEN?

'Science is a first-rate piece of furniture for a man's upper chamber, if he has common-sense on the ground floor.'

O. W. HOLMES. THE POET AT THE BREAKFAST TABLE

It seems superfluous to ask, What is a garden? Yet, contemplating our answer, we shall probably appreciate some aspects of our subject that are apt to be overlooked. A garden is essentially a place where we tend plants, so that its peculiarities are probably best realised if we contrast it with an area of wild vegetation which has been entirely uncared for. A primitive piece of woodland would serve our purpose. It is characterised by a recognisable architecture—a roof of trees, an upper story of shrubs, and a ground-floor of herbs. Furthermore, the structure of one woodland is very much like that of another, although the trees may be different. So, too, a Heather moor often presents a carpet of mosses and lichens beneath the canopy of Ling and Whortleberry, whilst the even surface of a Reed-fen conceals tiers of herbs of decreasing stature.

The plants which form such wild types of vegetation grow together in a definite way. That is to say, they form real communities in which the varied species maintain themselves, in fluctuating numbers of individuals, comparable to the doctors, butchers, bakers, lawyers, politicians, burglars, etc., who make up a human community. Like the constituents of the latter, some are clearly essential to the well-being of the whole, others might well be dispensed with, or are even harmful; but they all persist because each can occupy a definite niche in relation to the structure of the entire community. Though the population varies with respect to the number of its individuals, the kinds of which it is composed remain relatively constant so long as there is no artificial interference by man. Each kind of plant that finds a permanent place in the wild community maintains itself

there by virtue of a fitness for its situation. It must there attain a certain degree of vigour and produce not less than a certain number of offspring, otherwise it will be overgrown by its neighbours or the gaps brought about by death will not be filled.

How striking is the contrast afforded by our gardens! These comprise an artificial assemblage of many kinds of plants, the nature and numbers of which are mainly dependent on our arbitrary whims and fancies. Some that we grow are only too patently unfitted for the conditions in which they live, and many more fail to produce offspring, and so when they perish must perforce be replaced by artificial propagation or by importation. The plants of a garden grow not where they will but where they must.

Furthermore, as any derelict garden brings home to us, the species we cherish only survive so long as we tend them. Human interference is as essential to the maintenance of the artificial community of plants we term a garden as is the absence of human interference for the maintenance of really wild natural vegetation.

This striking contrast brings home to us the fact that the seeming stability of the wild community is an outcome of the continuous competitive struggle for existence by which all plants not well fitted for their particular environment become eliminated. In a garden, however, competition is usually at a minimum, though never completely in abeyance. The garden is, in fact, an unstable community which only continual labour maintains in a seeming stability. Many of the garden operations, such as removal of weeds, cultivation of soil, replanting, etc., have as their direct or indirect object the minimising of competition. Hence it is important to understand how competition operates between species and what are the weapons with which one plant competes with another.

The green-leaved plants, with which we are alone concerned at the moment, contain in their leaves a mixture of four pigments which are collectively known as chlorophyll. This green mixture has the most important property of being able to

capture radiant energy from the sun's rays (or other source of light) and to convert this into energy available for chemical reactions. By this means green plants possess the unique capacity for combining water, which they obtain from the soil through their roots, and carbon-dioxide, which they obtain from the air via their leaves, into sugars. These sugars either serve as sources of energy to drive the machinery of the plant's body, or to be further built up into still more complex organic compounds through combination with various inorganic salts taken up from the soil in solution. The complex substances so formed add to the living and dead material which constitute the substance of the plant.

For the maintenance of life in a green plant, light is thus essential, since upon this its food-supply depends. It is therefore scarcely surprising that the most frequent manifestation of competition between species is due to interference by the foliage of one species with the supply of light which reaches the leaves of another.

It will be evident, then, that the height to which a plant can grow often becomes an important and sometimes a decisive factor in determining its capacity for survival in uncultivated areas. For the higher a plant grows the more it can shade its neighbours and the less the risk of being itself shaded. It may, indeed, be said that, in the wild state, there is no respect for 'ancient lights.'

Climbing plants save any considerable expenditure of their substance in developing stout stems since they rely on the support afforded by more robust neighbours. Most are native of the margins of woods and forests where they quickly reach the light and develop their foliage to the detriment of the shrubs and trees on which they scramble or twine.

Fields, which were once arable land but which have passed out of cultivation, show a gradual replacement of low-growing grasses and herbs by successively taller vegetation, so that the grassland passes into a thicket of shrubs, and this in turn finally passes into a woodland of trees. But, even when the tallest trees have formed a continuous canopy, we find that some



shrubs and some herbs still remain, despite their lower growth. This is due partly to differing degrees of efficiency amongst plants in the utilisation of the sunlight which falls on them and partly to the small amount of carbon-dioxide in the atmosphere (0.03 per cent) which as a consequence limits the rate at which the process of manufacture of sugars can go on, and so renders a high light intensity superfluous. It is as though, in a manufacturing process, we had to use several different raw materials in definite proportions: an excess of any one would then only be of value if the others were proportionally increased. Conversely, the raw material which is most below its appropriate proportion will practically determine the rate of manufacture.

This principle is of fundamental importance to the gardener for it emphasises the futility of increasing any one requirement for plant growth (unless there is an actual deficiency in that respect), whether it be warmth, light, water, an artificial fertiliser, or the amount of carbon-dioxide, unless the other necessities for growth are proportionally increased. The proportional relations are, however, complicated by the fact that anything which promotes the general health of the plant will enable it to support a slight deficiency in other respects without loss of vigour; as, for instance, a good supply of water, which will enable a plant to tolerate greater shade than it would endure under drier conditions.

Owing to the small proportion of carbon-dioxide in atmospheric air, this necessity for plant life is often the condition which determines the rate of manufacture of food by the plant. Since the rate of food production of many species is limited by the supply of this gas, they are unable to take full advantage of bright sunlight. Indeed, a degree of shading that reduces the light intensity to only one-third of that in the open may still enable these plants to function on a bright day as rapidly as the supply of carbon-dioxide will allow. Such species may grow as vigorously in partial shade as in the open, or even more so, since they gain the advantage of shelter from wind and do not suffer the destruction of chlorophyll which bright light may cause.

Some of the food made by the plant is used, as already stated, to drive the plant's machinery. This food is broken down by a breathing process which goes on day and night, and the energy thus liberated is utilised for various purposes. Such breathing and consequent utilisation of food material is going on even when the plant is not growing. So, if we regard the amount of food which the plant manufactures as its income, we can consider the amount used in breathing when the plant is not growing as the working expenses, and it is the balance which remains that is available for growth, for the production of flowers and fruit, and for the provision of a dowry for the offspring.

Now the working expenses differ considerably amongst different species of plants, and it is in general true that those species which can endure the greatest shade are those in which the working expenses are lowest. Even with a very small income they are still able to save a little and so to grow and, it may be, produce offspring, though perhaps only by vegetative means.

The natural habitats of plants are the best guide to their requirements as regards light intensity. The *Aspidistra*, which comes from the shady forests of the Himalayas, China, and Japan, is an example of an extreme 'shade plant,' hence its complacency in the dim interior of the villa window and the even darker recesses of living-rooms where the light intensity may be less than one hundredth part of that in the open. We do not, of course, realise how dull the light is in our rooms, or even in our glasshouses, because our eyes adjust themselves by enlargement of the pupil as the light intensity decreases. Quite a clean piece of thin horticultural glass will reduce the light by more than a tenth and so soon as it gets dirty the interference is much greater.

By appropriate association of tall sunshine-loving plants with shorter plants which prefer shaded conditions we can reduce the competition for light in our gardens and plant our beds more thickly.

Active growth only takes place when a plant is well supplied with water, so that besides the struggle for light another way

in which competition may operate is when the roots of two plants are withdrawing water from the same volume of soil. To visualise the significance of this it must be remembered that very rarely is it the case that a plant depends solely for its water supply upon the soil actually occupied by its root system. As water is withdrawn by the root from the soil immediately around it a flow is set up from the soil further and further away. Thus the roots of one plant may be competing for water with the root system of another, although their respective roots are nowhere in contact, the more intimate the relation the greater the struggle. It is evident that the type of root which a plant has may play no small part in determining its success or failure to secure an adequate supply of water in the presence of other root systems occupying the same soil.

Finally, plants may be, and very often are, competing for the supplies of mineral salts that are present in the soil as a dilute solution. The season at which the plant makes its greatest growth is often a matter of importance in this connection, since two species, both occupying the same soil, may be able to grow successfully together provided their maximum demands for the food materials in the soil are at different seasons of the year.

Of the various ways in which plants compete with one another the chief only have been mentioned, namely for light, for water, and for mineral salts. By spacing his plants, by cultivating the bare soil between them, the gardener attempts to minimise the competition for light and water, whilst the application of manures is aimed at ensuring an adequate supply of mineral salts for the needs of all. Nevertheless the competition is by no means eliminated and can only be reduced to negligible proportions by a considerable sacrifice of space and appearance, whilst in the seed-bed the problem is always apt to become acute.

In the cultivated parts of the garden there is often no competition for light, though this may occur in a crowded herbaceous border. We say 'may occur' because, as we have already stated, there may be moderate shading for some species without any actual competition. Usually the interference between

plants in a well kept garden is almost if not entirely beneath the surface, where competition for the water and dissolved mineral salts is often appreciable.

It is an open question whether and to what extent the root system of one plant may have a directly harmful effect upon the root system of another. It appears certain that the roots of grasses have an effect on other plants which is quite apart from that due to their removal of water and food substances from the soil. Such a direct effect is quite likely to be due to substances produced during decomposition of the older roots which have ceased to function and have died. The numerous fine roots that grasses produce only absorb and live for a relatively short period and are being continuously replaced by younger, newly formed roots, whilst the older decay away.

Hence, even if, as is not improbable, all decaying roots produce substances which are harmful to growth, these will naturally be formed in greater concentration by grasses than by plants whose roots serve for longer periods and have their finer branches more widely distributed in the soil. So, too, grass near the roots of young fruit trees often checks their growth, and the ill effects of other plants with numerous fibrous roots upon their neighbours will be familiar to many and are likewise a consequence of toxic substances. All too little, however, is known respecting the effects of different kinds of plants on one another, and the observant gardener could do much to increase our knowledge of this important subject.

The distance apart at which the roots of different kinds of plants, or different individuals of the same kind, cease to have an appreciable effect upon one another may be expected to vary with the kind of soil in which they are grown, with the weather conditions, and with the kinds of plants concerned, but to what extent remains to be determined by careful study.

Nevertheless, if competition between different individuals is usually severe in the garden only where the vegetation is dense, it is quite commonly a very potent influence affecting the growth of different parts of the same individual. This idea, of the various parts of the plant's body competing with one another

for the necessities of life, is perhaps an unfamiliar one in theory, though in practice the gardener often carries out operations which depend for their efficacy upon this principle. For example, the practice of disbudding Sweet Peas, Carnations, Tomatoes, etc., has for its purpose what is in effect a demonstration of the fact that the flower-buds are all competing with one another for the available food supplies, since the more buds we remove the greater will be the amount of food available for those that remain.

In general—there are a few exceptions—every leaf has a bud immediately above its base, in the angle between the leaf and the stem, and every such bud is potentially capable of growing out into a branch or a flower. If all these buds were to develop, however, most trees and shrubs would be even more of a tangle of branches than they actually are.

Usually the food supply is only sufficient for the development of a few of the buds on each twig, and the consequent competition results in many of the buds remaining undeveloped. By pruning we can, however, divert the food material towards some of these dormant buds, so that subsequently they grow out into branches instead of the other buds which have been cut away. In the lorette system of pruning apple trees we may so restrict the demands on the food supply that additional buds become formed above the leaves that remain and three buds, in place of one, will develop above the leaf. The two additional buds arise at each side of the normal bud, in the axils of the stipules. So, too, we pinch out buds from our Tomatoes and Sweet Peas, in order that more food may be available for those which remain.

Once we realise the true significance of these familiar facts, it will be evident that the same principle of internal competition must apply, not only between bud and bud, branch and branch, or flower and flower, but even between leaf and leaf.

If, by manuring and watering, we so increase the available supplies of food as to reduce or even eliminate the operation of natural selection between the abundant rudiments of leaves, buds and flower-buds which the plant forms, we must not be

surprised if there results such a profusion of development as to necessitate artificial checking if the health of the plant is to be maintained. Hence we cut out the profusion of growth in our trees and the superfluity of twigs in our bushes. If we want exceptionally large flowers we must sacrifice number to size.

The perennial shoot systems of herbaceous plants being buried beneath the soil cannot be pruned in the same manner. Yet it is evident that here too there must be competition for food between the various parts, just as much as between the parts of the overground shoot systems. Each underground branch of a Michaelmas Daisy or of a perennial Sunflower demands its share of the food formed by the leafy shoots and absorbed by the roots. The practice of periodically digging up herbaceous perennials and dividing them before replanting is a crude way of pruning the underground shoot system and so diminishing the competitive struggle.

The more freely these buried stems branch the more important such division becomes. In the old type of Michaelmas Daisy the underground stem not only branches freely but the branches attain some length before their tips turn upwards into the light and air. Since most of the roots are formed where the underground branches bend upwards to form the leafy shoots, the competition between the root systems of the different branches is somewhat reduced by this spacing. Many modern varieties of Michaelmas Daisy branch somewhat less freely, but since they spread outwards at a much slower rate, competition between the underground branches is perhaps even more severe. Hence they must be lifted and divided just as often as the older and more rapidly spreading varieties if the standard of vigour is to be maintained.

The decreased vitality of the centre of an old clump of many an herbaceous perennial, followed later perhaps by a dead central patch, is a familiar result of failure to replant. Such an effect is not due merely to depletion from the soil beneath the central region of those mineral salts upon which the species makes the greatest demands, but also to the diminished water supply and to accumulation of the products of decay. The

practice of replanting only the peripheral parts of a clump thus ensures propagation by the parts which are least likely to have been enfeebled by adverse conditions.

Briefly, then, a garden is primarily a place where we grow and tend many different kinds of plants, and so artificially protect them from severe competition, and the survival of most is dependent on the degree of our success in this respect. The competition of shoot systems for light and space we can visually recognise and check; the more subtle competition underground is sometimes even more important, but it is invisible and so too often forgotten.

CHAPTER II

THE SOIL

*. . . 'thrusting its roots downward and spreading them wide
taketh tenure of the soil, and from ev'ry raindrop
on its dribbling passage to replenish the springs
plundereth the freighted salt, while it pricketh upright
. . . anon to disengage buds that in tender leaves
unfolding may inhale provender of the ambient air.'*

ROBERT BRIDGES. THE TESTAMENT OF BEAUTY

*'Where grows? Where grows it not? If vain our toil
we ought to blame the culture not the soil.'*

POPE

How often have you heard the question 'What shall I do with my soil?' The soil is in fact, in more senses than one, the raw material out of which the garden craftsman creates his dreams or raises a monument to his defeat. Indeed, it is no exaggeration to say that our success in the garden depends in very great measure upon the extent to which we realise not only the potentialities of our soil but also its limitations.

By unstinted expenditure of labour, time, and money it is possible to grow most sorts of plants, that the climate permits, in most gardens. But if we merely try to imitate our neighbours, to grow everything that we see others grow, we may indeed attain a monotonous mediocrity but we shall scarcely achieve that measure of individuality that is essential to success. The only kinds of plants that are really worth while growing in our garden are those which will grow as though they enjoyed life there, and this can only be attained if we know intimately the characteristics of our soil and the possibilities of its exploitation and improvement.

We all know that soils vary greatly in texture, in colour, and in many other qualities, yet despite their diversity of character all true soils have this in common, that they contain five different types of constituents, namely, the mineral matrix; the decayed

remains of plants and animals; microscopic plants and animals that are alive and active; the watery solution in the soil, and finally a soil atmosphere.

The mineral matrix consists of particles of very diverse sizes derived by fragmentation from rocks which have undergone varying degrees of chemical change. Such mineral particles when of large size we term sand, whilst the very minute particles which have become both chemically and physically altered by the continued action of the weather are what we term clay.

Mixed with the mineral particles are the remains of the dead bodies of plants and animals. The dead twigs and leaves that are shed in autumn, by trees and herbs alike, contribute in part to this organic material, annually enriching the soil from above. Every gardener knows and appreciates the value of 'leaf mould,' which is of course the much altered product of these fallen plant remains. But the roots which penetrate into the soil, though when they die they may at first form toxic substances, ultimately contribute also to this decayed organic material, which, whatever its origin, is of great importance for the green plant, both as a source of food material, and because it has a great capacity for retaining moisture.

When we dig any piece of ground its level is temporarily raised, though gradually the soil settles down as before. Our digging has obviously separated the particles so that the soil occupies a larger volume. Even when the soil is compacted, however, there are still minute spaces between the soil particles. These spaces are filled partly by gases and partly by liquid. If we were to take a cube of garden soil and immerse it in a known volume of water and then break up the soil, the water and soil together would be found to occupy a smaller space than the two occupied separately. If we had dried our cube of soil before putting it in the water, the difference would be even greater. By breaking up the cube of soil we enable the water to replace the air that formerly occupied part of the space between the soil particles. The difference between the volumes before and after mixing is a measure of the pore space, and in a normal garden soil this would amount to about two-fifths of the

volume of soil, if all the water had been dried off. Actually in natural conditions about three-quarters of the pore space in the soil will be taken up with soil water, and the rest, less than a tenth of the whole volume of the soil, will be occupied by soil atmosphere.

The soil water contains dissolved salts, and is therefore known as the soil solution. It is an important source of supply of food materials essential to plant life, and it is present as films covering the mineral particles and the organic fragments.

The soil atmosphere consists of the same gases as are present in the air, nitrogen, oxygen, carbon-dioxide, etc., but in different proportions. The oxygen is of importance for the breathing of the roots, and in waterlogged soils is sometimes so low in amount as to result in injury to the plants growing upon them. Usually the chief difference between the soil atmosphere and the air is the higher amount of carbon-dioxide which the soil contains, and this, when too concentrated, may have a very deleterious effect upon root growth. Heavily manured soils often produce this gas in considerable amount, and if the texture of the soil be such that the carbon-dioxide does not readily diffuse into the air it may accumulate in the soil and cause injury to the plants growing in it. The plant uses the carbon-dioxide which it absorbs by its leaves, so that the diffusion of this gas from the soil into the air is beneficial as enriching the supply.

The fifth constituent of the soil is a teeming population of microscopic plants and animals, many of which, especially the plants, are essential to the well-being of the green plants we grow. Particularly is this true of the plants we call bacteria which are in great measure responsible for the conversion of the remains of the larger plants which are dead into a form which can be used by those which are living.

The soil is then a complex structure of mineral fragments, organic material, soil solution, soil atmosphere and living micro-organisms. Let us see how some of the variations in these components affect the plants which the soil supports.

The water which falls upon the ground in the form of rain or

snow, or condenses in the form of dew, will be of little value unless it is retained near the roots of the cultivated plants. On a coarse sandy soil, in which the mineral particles are relatively big, the rain drains so quickly away into the subsoil that even after a heavy shower the soil soon becomes dry and our plants suffer. At the other extreme a clay soil, in which the mineral particles are very small, may have so close and even a texture that the water is held on the surface as a puddle and is mostly lost by evaporation into the air. Clearly something between these two extremes of texture, such as a loam, is far more favourable to plant life. Indeed, most gardeners who are not favoured by nature in respect of their soil get weary of reading that such and such a plant 'grows best in a good loam.'

That water drains quickly through sand means that it can move readily through the large air spaces of this coarse-textured soil, so that a plant rooted in sand can readily obtain what water there may be. In the clay soil, on the other hand, water, though more plentiful, can only be drawn up by the plant with difficulty. This is because the pore space in a clay soil, though it often totals more than in a sand, is present as such extremely fine channels that the resistance to water movement is considerably greater.

The stickiness of clay is a property associated with the extremely small size of its particles. If, however, we add lime to the clay soil, these minute particles collect together in clumps and it becomes, as we say, "flocculated". In this state the stickiness disappears and the texture becomes lighter and more porous. The flocculated condition of the clay will remain until the lime is dissolved out by the action of rain, when the stickiness will once more assert itself. But, so long as we lime our clay, we can maintain a good tilth, and water and air will move with sufficient freedom through it, so that the roots of plants can take up adequate moisture and breathe freely.

By digging manure into a clay soil we can not only increase the food supplies but at the same time loosen the texture. A dry sandy soil can also be improved by adding organic material in the form of manure or leaf mould, since the worst feature of

the sandy soil, its poor power of holding moisture, is thus remedied by the great capacity for retention of water that such organic matter possesses.

But, as sand grains do not supply food material whereas clay particles do, a reasonable proportion of clay is desirable. Hence the merits of loams, because they contain both clay and sand and tend to combine the virtues of both.

An open texture in a soil is desirable for various reasons. It allows roots to penetrate readily with a minimum expenditure of energy, so that the plant is able to develop a more extensive root system than on a denser textured soil such as a clay. Further, a loose texture enables the roots to breathe freely, as the oxygen of the air diffuses readily into the interstices of the soil, whilst the carbon-dioxide, which is formed by the respiration of the plants and animals in the soil and which in high concentrations checks root development, can diffuse outwards into the air.

The value of continuous cultivation of the soil is in part due to the destruction of weeds that compete for light and food with the plants we are encouraging, but even more is it beneficial from its effect upon the soil texture. Nevertheless, too loose a texture is also undesirable. A plant depends for its water, and the contained salts, not only upon the films which cover the soil particles which are actually in contact with the root system, for these would soon be exhausted, but also upon the rapid replenishment of these films by the flow of water from the films of liquid on particles further and further away. This is only possible if the films are in contact with one another, since the movement of water vapour is a slower process. If a soil has too open a texture the continuity between the liquid films is broken and water movement is much less rapid. It is, of course, for this reason that when planting in freshly dug ground we must press the soil firmly around the root.

As water is present in the soil in the form of films covering the soil particles, the amount of rain which is retained by the mineral fragments is greater when these are smaller, since, as the size of these particles decreases, their combined surfaces become larger in proportion to their total bulk. For, though the

individual particles are smaller, there are far more of them and small particles have proportionally larger surfaces than large particles. It has been estimated that if we could spread out the surface films of all the particles in a cubic foot of coarse sandy soil as one continuous surface the area occupied would be about one quarter-acre, but if we could do the same with a clay soil the total surface in a cubic foot would be something of the order of two and a half to four acres. The reason why clay soils retain so much more water than sand is therefore clear, but, as we have already said, the channels in which this water is held are so narrow in the clay soil that much of this water is only obtained by the plant with difficulty.

The retentive capacity of organic matter for water is so great that when more than five per cent is present in a soil its effect may completely mask differences in water-retaining capacity due to size of the mineral fragments; so that a sandy soil with a high organic content will retain more water than even a clay soil which has very little organic material in its composition. Well, we can easily add organic matter, in the form of farmyard manure or leaf mould, etc., and clearly our soil if it be sandy will require the addition of a larger quantity than if it be a clay. But it is possible to overdo the addition of manure, especially to a heavy soil, which we might render too damp.

The effect of large additions of organic matter may be to render the soil too acid, since acid substances are produced freely in the process of decomposition, especially in the early stages of decay. Hence well-rotted manure is always preferable to fresh manure. Many plants are, indeed, very intolerant of green manure, both because of its acidity and also because at this stage it produces so much carbon-dioxide that the breathing of the plants' roots in the soil, and their growth, may be seriously interfered with.

Acidity in the soil can be tested by means of the colour indicators sold for the purpose, but this condition is often shown by the prevalence of certain weeds, such as Creeping Sorrel and Spurrey, that are tolerant of acid conditions, or even by the occurrence of that disease of members of the Cabbage tribe

known as club-root caused by a 'slime fungus.' It is worth noting that the influence of acidity on plants is often indirect. For example, Chickweed, Mouse-ear Chickweed, Dandelion, and Self-Heal are all quite tolerant of acidity as such, but relatively sensitive to alumina which is brought into solution in many soils when they become sufficiently acid. Thus these weeds may flourish in an acid sandy soil which contains but little alumina, whereas they may be completely suppressed on an equally acid clay in which the alumina content is high.

Some cultivated plants such as Rhododendrons flourish best in soils that are markedly acid, but most cultivated plants prefer soils that are mildly acid or neutral. Acidity can be cured by the addition of chalk or lime, but if due to the use of too fresh manure the lime will merely accelerate decomposition and cause an even more copious output of carbon-dioxide; so that for plants intolerant of poor soil aeration the effect of our remedy may be even worse than the trouble it was intended to cure.

Chalky soils have very definite properties. Physically they are usually light and heat up quickly in the sun; chemically they are generally deficient in organic material and in potassium so that they are often much improved by additions of farmyard manure and by the use of potassic fertilisers such as Kainit.

The chemical constituents that plant roots absorb from a soil are mostly not taken up in the form of molecules but in the form of the ions into which these molecules are dissociated when in dilute solution. There is a constant interchange of ions between the roots of the plant and the soil. A calcium, sodium, or potassium ion, for instance, passes into the root in exchange for an ion bearing a similar electrical charge passing out, most probably an hydrogen ion. Or ions of nitrate are absorbed in exchange for hydroxyl ions (OH) given out. These free hydrogen and hydroxyl ions are produced by the root in respiration so that a check to the breathing of the root may adversely affect the absorption of essential food materials. Also the intake by the plant of one kind of nutrient ion is influenced not only by its concentration in the soil-solution but also by the concentration of other ions present.

The ions of calcium retard the absorption of potassium and of iron as well as of certain substances deleterious to plants such as alumina. It is owing to the antagonism of the calcium ion for the absorption of iron that in very chalky soils plants may show a deficiency of green colour (chlorotic) since the development of chlorophyll is dependent on the presence of an adequate supply of iron.

Such antagonism, which may occur in any soil, is greatest when the proportions between the plant nutrients is most unbalanced, which emphasises the fact that in applying artificial manures it is important to remember that here, as in so many other matters, because a little is good a lot is not necessarily any better, but may indeed be actually harmful.

Plants such as most *Rhododendrons*, *Azaleas*, *Eucryphia pinnatifolia*, *Styrax*, etc., are often spoken of as lime haters. Others, such as *Buddleia variabilis*, *Rhus cotinus* and *Spartium junceum* love lime. But we must be careful not to assume that because one species in a genus likes lime another will also flourish in a chalky soil. Most *Ericas* will not tolerate a



chalky soil, but *Erica carnea* and *E. mediterranea* love it. There are two closely allied species of stemless Gentian both at one time known by the name of *Gentiana acaulis* and both in cultivation. One of these, now known as *G. Clusii*, which has bright blue flowers, is a native of limestone rocks in the Alps, whilst the other, known as *G. excisa*, which has a darker blue flower streaked or spotted within with green, is a lime hater. So too, we can grow *Primula auricula*, *Anemone alpina*, *Lithospermum purpureo-coeruleum* or *Rhododendron hirsutum* on calcareous soils, but not their immediate relatives *Primula viscosa*, *Anemone sulphurea*, *Lithospermum prostratum* or *Rhododendron ferrugineum*.

But the way of the gardener is hard, for even such preferences can sometimes be modified by local climatic and soil conditions, and nothing is more surprising than the way in which 'difficult' subjects often grow best in cultivation under conditions quite alien to those which the plant appears to demand in its native haunts. The only royal road to success is by experiment, but do not forget to make careful notes as to exactly what you did; memory is apt to be a poor finger-post.

When we trench a garden we loosen the soil to a depth of perhaps eighteen inches or two feet, thus allowing the roots freedom of development to that depth. But one is very careful in turning over the soil to retain the top spit at the top and the bottom spit at the bottom. This is because the top soil contains multitudes of beneficial organisms which are much fewer, or even absent, below and would suffer by being buried, whilst the relatively sterile soil from below would probably check the growth of whatever we planted in it if brought to the surface.

When the soil is repeatedly dug over with a fork, the finer soil tends to pass between the tines, whereas the lumps, and particularly the stones, are brought to the surface. Thus we are continually subjecting the soil to a crude sifting action that accounts for the movement of stones towards the surface. Because of this, aided by rainwash, in gravelly areas we find a bed which has been cleared of stones become, in a few months, nearly as stony as before. Hence the popular belief of countrymen that 'stones grow' has originated, so here as in many such

superstitions, there is sound observation behind the fanciful explanation.

Amongst the teeming microscopic organisms that are to be



Eucyphia Pinnatifolia

found in soils none are more important to the life of green plants than the bacteria which are responsible for bringing about chemical combination of the nitrogen of the air and converting it into a form which can be absorbed by roots. Despite the fact that so large a part of the air consists of nitrogen, the green

plant is incapable of using this directly. The nitrogen that a plant requires is in fact mostly taken in by the roots in the form of nitrates. As the living material of the plant contains nitrogen as an essential constituent, it is evident that a continuous supply is necessary for growth and health. But nitrates are readily dissolved in rainwater, so that after a heavy fall of rain most of these will have become washed down into the subsoil. If it were not for their continual renewal by the action of nitrogen-fixing bacteria, most plants would suffer from nitrogen starvation.

Some of these minute organisms that fix atmospheric nitrogen live freely in the soil. For their well-being they require that there should be some calcium carbonate, a supply of organic matter and that the soil should not be very acid. Usually one can ensure the last by the addition of plenty of lime. But these beneficial nitrogen-fixers are a source of food for the microscopic animals termed protozoa which also inhabit the soil and which sometimes abound in such numbers as to interfere materially with the supply of nitrates. The process of partial sterilisation of soil, by steam or toluene, depends for its efficacy upon the greater susceptibility of the protozoa to such treatment than of the bacteria. As a consequence, the numbers of the latter increase and the soil fertility is enhanced.

Other nitrogen-fixing bacteria live in the swellings which are found upon the roots of members of the Pea family, such as Lupins, Galegas, Broad Beans and Scarlet Runners. The value of Vetches as green manure dug into the soil is largely due to the enrichment of nitrates which the bacteria in their roots have produced. The bacteria occur in the soil itself, but they do not, apparently, fix nitrogen until they enter the roots of an appropriate plant, where they benefit from the organic acids which the root cells produce. Their entry into the root takes place through the root hairs at a phase in the life cycle of the bacteria when they are capable of movement in the water films. This condition, and therefore the probability of entry into the root, is stimulated by the addition of phosphates. As these root bacteria are more tolerant of acidity than those nitrogen-fixing

types which live freely in the soil, they are of considerable importance in soils poor in lime.

There are present in the soil many other kinds of bacteria, of which we need only refer to those that are responsible for decomposing the organic material which we add in the form of manure—a function which is shared by the soil fungi (mostly moulds). These require nitrogen for their activity, and hence the addition of fresh manure may lead to temporary nitrogen starvation. When we burn soil, or heat it very strongly, we of course kill all the living things it contained, and this soil will remain comparatively infertile until certain harmful substances, formed in the soil through the heating, have become oxidised by the air and the burnt soil has again become infected with the beneficial organisms.

The living content of the soil is in fact a vast population of many different types, some of which are, as we have seen, very beneficial, others, such as certain bacteria which break down nitrates or the parasitic nematodes which feed upon our Phloxes and Narcissus bulbs, are definitely harmful. The soil that we term fertile is one in which we maintain an appropriate balance in this population. It is too complex a problem for the gardener, not equipped with a laboratory, to do more than find by experience the conditions necessary to maintain a healthy condition, but too acid a reaction or excess of organic material are perhaps the most frequent causes of an unbalanced state. Soil reaction, soil aeration, water content, and soil temperature, are all conditions that influence the susceptibility of plants to disease, but a state which discourages one pest may promote attack by another. For instance, though acidity is unfavourable to potato scab it is favourable to the development of club-root.

It is because the soil is so complex in its composition and structure, so varied in its influence on the plants that grow in it, that the gardener must needs be an experimenter. He must, however, learn to vary but one condition at a time, and see that he has a standard of comparison. If, for instance, he wishes to find whether, on his soil, Sweet Peas really do grow better

if leaf mould is placed at the bottom of the trench, then two rows should be treated exactly alike in all respects except that one has leaf mould and the other has not. Also, if a garden is not very uniform in respect to soil conditions, it by no means follows that a treatment successful in one part will be equally so in another, so that our experimental rows must not be situated in different parts of the garden but in situations as comparable as possible.

CHAPTER III

SUNLIGHT AND SHADE

'The great majority of educated people have no real conception of the sun's contribution to their existence.'

M. O. FORSTER. PRESIDENTIAL ADDRESS CHEMICAL
SECTION BRITISH ASSOCIATION 1921

GREEN PLANTS may be described as the world's greatest chemists. It is these alone amongst the living organisms upon this planet that are able to manufacture the simple raw materials, provided by the air and the water of the soil, into complex food materials which serve not only as food for the green plants themselves, but for almost all other living organisms, whether non-green plants or animals.

It is this characteristic which makes green plants occupy such a unique position in the world. Without them almost all forms of life would come to an end. One must say 'almost' because there are a few plants which are not green, such as the Sulphur and Iron Bacteria, that do not need substances formed by green plants, since they obtain energy from simple oxidation processes of inorganic substances.

The caterpillars which feed on our Cabbages and the slugs that devour our Lettuces obtain energy from the green plants they consume. The birds which eat the slugs and caterpillars obtain their energy second-hand, but they are actually just as dependent on green plants, though indirectly. It may indeed be said that all the animals which are to be found in a garden, in common with animals in general, are either directly or indirectly dependent for their food upon the green vegetation.

The combination of simple chemical substances into complex ones involves the equivalent of a considerable amount of work. In other words, energy is required to effect this change, and the unique quality of green plants to bring this change about is due to their capacity for building up that mixture of very complex

pigmented substances, termed chlorophyll, which makes them green. This chlorophyll, as already stated, has the quality of absorbing that form of energy which we term light and converting this light energy into the energy required for chemical change. The plant uses this chemical energy to combine hydrogen and oxygen, obtained from water absorbed from the soil, with carbon obtained from the carbon-dioxide gas in the air, to form sugars. These sugars may be further altered, or combined with substances absorbed from the soil, to provide the living substance of the plant or the non-living framework in which this living material is supported. These sugars are thus essential, both for the building of the cells of which the plant is composed and for the formation of the living contents of these cells.

But besides furnishing the raw material out of which fresh plant substance is formed, these sugars also serve as a potential source of energy for the plant. They are, in fact, the chief form of plant food, serving as a store of energy and material, often, as a matter of convenience, converted into starch, but reconverted into sugar when required for use. By food we mean a substance which can furnish energy to a living organism as and when required.

Put concisely, energy is obtained from food by a process of oxidation in which a complex substance is broken down into its simple constituents, with a liberation of energy equivalent in amount to the energy which was utilised in the building up of the complex substance. The amount of energy which the green plant must absorb to form a pound of sugar would be adequate to bring approximately four gallons of cold water to boiling point. Conversely, we could boil this amount of water by burning a pound of sugar, if we could avoid all waste of heat. The chemical products of burning the sugar would be carbon-dioxide and water: the same substances that were utilised in its formation.

Plants, like animals, respire continuously whilst they are alive—that is, they take in oxygen and give out carbon-dioxide and water vapour, the oxygen being used in the ‘burning’ of food substances with a consequent liberation of energy whilst the

carbon-dioxide and water vapour so formed are the waste products of the process. In daylight, however, the plant is taking in carbon-dioxide from the air to form food, much more rapidly than it is produced in the process of respiration.

Since the energy necessary for the production of these essential sugars is provided by the sun's rays, light is absolutely indispensable for the life of green plants. Only plants which are not green, such as the mushrooms we grow in cellars or the fungi which cause several diseases of the Potato, can grow without being in the light. These are able to do so because they obtain their energy second-hand. Such colourless plants either live as parasites on the live bodies of other plants and animals, or as saprophytes on their dead bodies; but in either type the source of energy of these colourless plants is complex material which was, at some time or other, built up by green plants with the help of the sun's rays.

All this brings home to us the importance of sunlight for plants, and, since the gardener is usually only concerned with the cultivation of those which have green leaves and make direct use of sunlight, it is evident that he cannot know too much of how sunlight affects plant life.

Light is merely one of the many manifestations of energy in the form of wave motion. Everyone nowadays is familiar with the very short waves which are known as X-rays and, at the other extreme, with the very long waves that our wireless sets receive. Between these two extremes is a very limited range of wave-lengths, apprehended by our senses as light or heat. The waves which cause the sensation of warmth are longer than those which give the sensation of light, and the waves which we sense as red light are longer than those which we call yellow, and still longer than those which give us the sensation of blue light. The ultra-violet light that has importance for the health of animals has wave-lengths just too short to give our eyes the sensation of light, whilst the infra-red rays, which on suitably prepared photographic plates will produce an image, are, on the other hand, of too long a wave-length to be perceived by the human eye.

The range of light we can see—the visible spectrum, as it is called—can be compared with the range of sounds we can hear. We can recognise individual colours just as we can recognise individual notes, but, just as if all the notes on a piano were struck together we should merely have a medley of sound, so when our eyes receive visible light of a great variety of wavelengths we have no definite sensation of colour as such, but a medley which we apprehend as more or less white light. The medley we call daylight we see analysed into its constituents in the artificial spectrum or the natural rainbow. Of these component rays of daylight, plants mainly utilise the red and blue portions for their supply of energy. Of invisible light, the ultra-violet may, in excess, be very harmful to plants, but otherwise it is not known to be of importance to them. At the other end of the scale, the infra-red rays are of value as a source of heat, but do not appear to be used by the plant directly for the manufacture of food material.

But, though all plants appear to make use of the same sorts of light, chiefly the visible red and blue light as mentioned above, yet, as every gardener is aware, some grow better in shade and others better in the open. For example, the Sunflower owes its name to the fact that it flourishes best in full sunshine, and will only endure a modicum of shade and remain healthy. On the other hand, a Geum will grow better in the shade than in full sunlight.

Let us consider why this is so.

As we have said, the sugars which form the basis of plant foods are built up from water and carbon-dioxide. This gas obtains access to the plant through numerous minute pores in the skin of the leaf. These pores, termed stomata, which are often confined to the under-side, are nevertheless so numerous that the intervening skin offers little obstacle to the inward diffusion of the gas. Some idea of their number is obtained from the fact that an average-sized apple-leaf will have over a million such pores in its lower skin; and in a garden strawberry there may be over a quarter of a million to every square inch of leaf surface.

The amount of carbon-dioxide in atmospheric air is very low—only 0.03 per cent—and so, although there are so many pores through which it can diffuse into the leaf, this low concentration puts a limit to the rate at which sugar can be manufactured in bright light.

In full sun there is plenty of energy to work the sugar-factory, but if one of the raw materials (e.g. the carbon-dioxide) is not absorbed from the air sufficiently fast, it holds up the rate of production. The leaves of some plants are so constructed that the gas can diffuse inwards readily and quickly, but in others the internal leaf structure is such that the gas can only diffuse inwards slowly. It is this difference that in great part accounts for the preferences amongst plants as regards sun and shade. For if, owing to its internal construction, the diffusion of carbon-dioxide into a leaf be slow, a large amount of the energy derived from light will be wasted. The plant will gain no advantage from being in the full sun. It will not make food any more quickly than if it were partly shaded, and at the same time it will get hotter and so evaporate more water. Also in bright light the supply of chlorophyll necessary to capture the sun's energy has to be continuously renewed, because bright light destroys it. Full sunlight is thus for such plants not only superfluous, but actually detrimental.

On the other hand, if inward diffusion of gas into the leaf be rapid, the higher rate of food production may compensate for these disadvantages. The faster food is formed by a plant, the more rapidly it can develop new leaves, and so present a still larger surface on which the light can fall. An appreciable proportion of the plant's output of sugar is thus expended in extension of the factory itself, so that the rate of manufacture increases like compound interest. Most of the income is 'put back into the business' until the plant begins to flower and fruit, when the products of manufacture are turned to other uses than extension of the factory.

But there is another aspect from which the effect of light upon plants can be considered. If we go into any wood in which the undergrowth has not been coppiced for some years we shall

probably notice such plants as the Yellow Dead Nettle and the Bugle growing freely and spreading rapidly by their runners, but almost entirely non-flowering. After the wood has been cut we find these same plants flowering profusely. The change is due to the increase of light. We see the same feature in many of our garden plants, but not usually in so spectacular a manner. The fact that many plants grow well in shade, even though they do not flower, shows that the light is sufficiently bright for them to make the necessary food for growth, but a greater amount of illumination is necessary for the production of their flowers than for the production of their leafy shoots.

Since plants situated in the shade run less risk of a check to their growth from excessive evaporation they are often able to spread more vigorously here than in the sun. On the other hand, too much moisture in the plant may itself check flowering. For example if Creeping Jenny be grown in a wet situation it flowers far less freely, even though fully exposed to the sun, than when grown in a drier place. This does not mean that the vigour of the Creeping Jenny (*Lysimachia nummularia*) is checked; on the contrary, it is apt in such damp places to become more rampant than ever, since the abundant food it makes is all directed towards growth, little or none being diverted towards flower and fruit formation. This is probably because the rate of intake of dissolved substances from the soil, particularly nitrates, is excessive as compared with the rate at which the plant is forming sugars.

Most gardeners have witnessed the spectacular success that often attends root-pruning of fruit-trees, particularly Pears, growing upon the moister types of soil. This is largely due to the check which the cutting of the roots causes upon the supply of water and substances in solution.

It will therefore be readily understood that the amount of light which our plants require to grow their best is not a definite amount, but varies with the other conditions of growth and also with their stage of development.

The effects of light are still further complicated by the fact that many of our garden plants are influenced not merely by the

intensity of light they receive, but even by the amount of the daily ration.

It might be thought that, provided a plant was grown in the right degree of shade or in the open, according to its capacity for using carbon-dioxide, the longer the period for which it was appropriately illuminated the more food it would make; and so the better it would grow. There are, indeed, some plants which appear to be able to work continuously in this way, and which grow better the longer the period for which we illuminate them.

If we grow *Cinerarias* or *Cucumbers* in a glasshouse which is artificially illuminated by night, so that they can make food continuously throughout the twenty-four hours, the plants mature more rapidly and flower earlier than if they had only been in the light during the daytime. Sweet Williams, *Nemophila* and *Lychnis Viscaria* will all bloom appreciably sooner if we supplement daylight by artificial light. But some of our garden plants that are natives of countries nearer the equator, where the length of daylight is short compared with our northern latitudes, instead of benefiting by an increase in the period of illumination beyond what they would receive in their native home, show a delay in flowering, or may even fail entirely to come into bloom. Such a plant is the garden *Cosmos*. Most gardeners know how often this plant does not flower until the days get shorter in the autumn; it may even become cut down by frost before it comes into bloom. If, however, we grow our *Cosmos* where we can prevent it being in daylight for more than twelve hours each day, it will be found to come into bloom quite normally and much earlier. Other such plants are *Chrysanthemums*, *Dahlias*, *Tobacco*, which also usually bloom when the days become short, but which by artificially shortened days can also be induced to bloom earlier. The effect of prolonged illumination on *Dahlias* is not only to influence the period of blooming, but to cause the roots to become fibrous instead of tuberous.

In contrast to these 'short-day' flowers are a number of kinds, chiefly native of northern climes, where the days are naturally long, which only bloom satisfactorily if illuminated for a longer

period than twelve hours each day. Such plants normally come into bloom in our gardens in the summer, when the days are long, and if sown too late in the season fail to flower unless we supplement the hours of daylight by artificial illumination for an additional period.

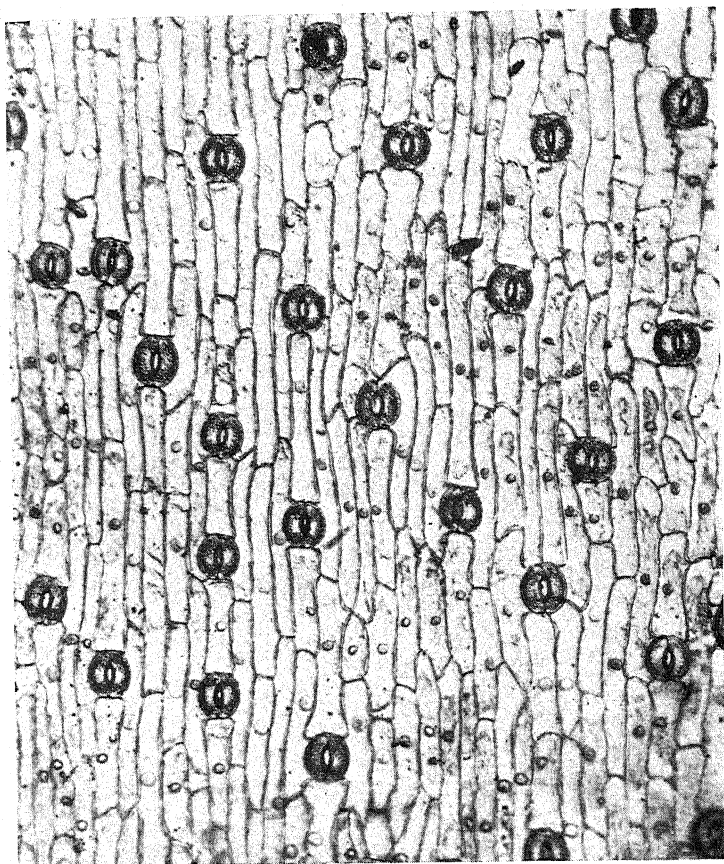
If we grow Love-in-the-Mist in daylight of only twelve hours' duration each day, the vegetative growth will be even greater than with a more prolonged period of illumination, despite the fact that the time during which the plant can manufacture its food is more restricted. But under this restricted period of daylight the Love-in-the-Mist, despite its vegetative vigour, fails to flower. This is true also of the Cone-Flower (*Rudbeckia*), Phacelia, Evening Primrose, Iris, and a number of others which are all 'long day' plants that need a long daily period of illumination if they are to bloom early and well.

Still other plants are apparently indifferent to the length of day; except in so far as they grow better and seed more freely the more hours of daylight they receive. Such plants can occur naturally in a great variety of latitudes, and it is scarcely surprising to find that they include some of the most cosmopolitan of our weeds. Chickweed and Groundsel can come into bloom and fruit at almost all seasons of the year, provided the temperature is not too low, because they are not particular as to the length of day, but utilise it equally, whether in long doses or short, for building up the food by which they grow and reproduce. On the other hand the formation of tubers by the Jerusalem Artichoke (*Helianthus tuberosus*) and the Potato is promoted by a short daily period of illumination. Both are natives of low latitudes.

Unexpected results may also be produced by differences in the intensity of illumination. For instance, if we grow Cucumbers in bright light, the proportion of male flowers will be high, whilst the plants can be induced to form an increased number of female flowers if the light intensity be diminished.

The shrub, or herbaceous plant, which is growing towards the side from which it is better lighted, is a familiar object, and bears witness to the fact that light also affects the direction of

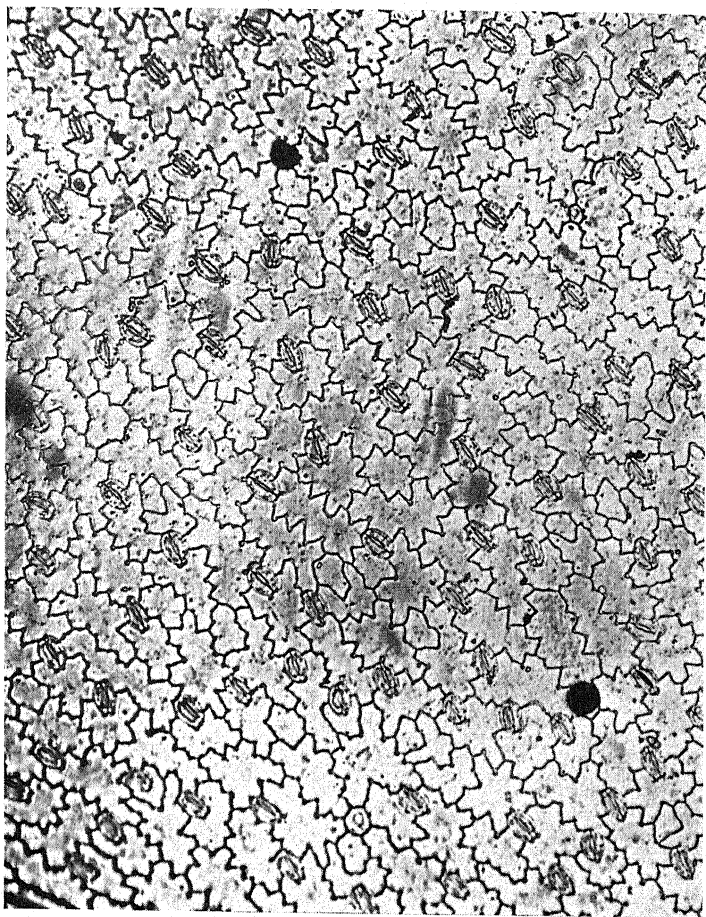
PLATE I



LEAF SKIN OF CROWN IMPERIAL

Showing oblong epidermal cells, many with a nucleus; and scattered pores each surrounded by a pair of guard cells [x ca. 180]

PLATE II



LEAF SKIN OF THE SCARLET PIMPERNEL

With epidermal cells forming jig-saw pattern and scattered stomata [x ca. 180]

growth. In our greenhouses such 'turning over towards the light' is an equally familiar feature, and is also due to growth taking place more rapidly on the more shaded than on the better lighted side of the stem.

Quite a small difference in the intensity of the light on the two opposite sides will be sufficient to bring this about. But it must not be thought that this is just a simple checking of the rate of growth on the better lighted side. The flower-stalks of the Ivy-leaved Toadflax (*Linaria Cymbalaria*), for instance, actually change their reaction to light at different stages of their development. In the flowering condition the flower-stalk grows more rapidly on the shaded side, so that it curves towards the light, but later on, as the fruit ripens, it is the illuminated side which grows the faster, and so the stalk bends away from the light. The horizontally growing rhizomes of Anemone, if they become exposed by removal of soil, grow down again, because the lighted upper surface grows faster than the lower darkened surface, and so the rhizome once more becomes covered with soil, after which it continues its horizontal course.

It is not only the direction of stems that is affected by light, but also the direction of leaves. For instance, the top shoots of a Privet hedge will be seen to have leaves arranged in alternating pairs spreading in four directions. But the shoots at the side of the hedge, which receive light from one side only, will be seen to have all their leaves in one plane, so that they all face the direction of the light. Similar differences can be seen in the erect and side shoots of Forsythia.

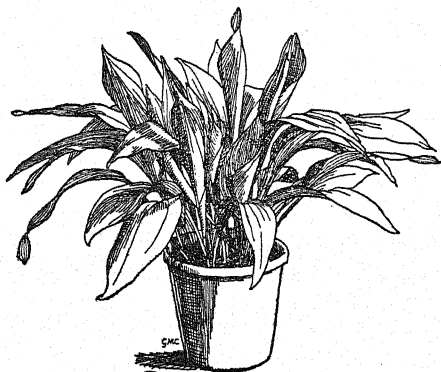
Some plants when growing in bright light place their leaves in a plane parallel with the direction of the strongest light, so that they are 'edge on' to the sun's rays, and the light they receive is proportionally diminished. The Compass plant of our herbaceous borders (*Silphium laciniatum*) is a North American example of such response to the stimulus of light.

Most roots are quite unaffected, as to the direction of their growth, by light, though a few, such as the roots of the Sunflower and Garden Cress, show a slight tendency to grow away from the light, whilst the roots of the cultivated Hyacinth tend



Evening Primrose,
Love-in-the Mist (or Devil-in-the-Bush), Cone Flower

to grow towards the light. The exact mechanism by which the parts of a plant take up a definite position in relation to the direction from which the illumination comes need not concern us here, but it is of considerable interest to the gardener to realise that plants can respond to the stimulus of light even when this is very feeble, and can in fact react to differences in intensity of illumination which are much too small to be discerned by the human eye.



The Aspidistra

The converse—the effect of shade—is commonly to induce an elongation of the main stem. Plants grown in the shade tend to become ‘leggy’ and, as already mentioned, often grow well vegetatively, but do not flower.

The tolerance of shade is markedly different in different species. The familiar Aspidistra is a striking illustration of a shade plant that has such a low expenditure of energy in respiration that even the extremely meagre light of a living-room enables it to manufacture sufficient food to leave over a small balance for growth. This is true also of our native Ivy, but, whereas the Aspidistra will even flower in extreme shade, the Ivy, in common with many other plants that will grow in deep shade, requires appreciably more light to induce it to flower.

It is important to recognise that the tolerance of shade is increased if the other conditions for growth are favourable. It is often because the soil underneath trees is too dry and is depleted of its nutrient salts that the herbaceous plants beneath the shade do not succeed; and not because the shade is too intense. Many of the plants most tolerant of shade are, as we

might expect, woodland species. The Primrose and Hellebores, Lesser Celandine, Lesser Periwinkle (*Vinca minor*), Baneberry, Trillium, Lily-of-the-Valley, and Solomon's Seal are all woodland species. But it must be borne in mind that most of these are natives of deciduous woodland, and produce their leaves early in the year, so that they manufacture a considerable amount of their food before the trees above cast their full shadow.

A number of herbaceous garden plants grow best in partial shade, often because of the slower rate of water loss from the leaves, but probably in part because of the deleterious effect of bright light upon the chlorophyll. *Campanula latifolia* and Leopard's Bane (*Doronicum*), on the drier types of soil, are apt, at the front of the border, to spend hot sunny days with drooping semi-flaccid leaves and never attain the stately dimensions they assume in partial shade at the back. There, in company with *Veratrum nigrum* and Bocconia, their leaves obtain shade and shelter, whilst they can rear their inflorescences into brighter light above.

It is the lower water consumption in the partial shade that renders Lettuce and Asparagus, Celery and Rhubarb, more succulent when grown under conditions of shelter. Further, in shade or complete darkness there is a much smaller development of the woody tissues, so that in this respect also their texture is improved. That is why we blanch our Rhubarb and Kale under chimney-pots and our Celery and Cardoon with paper sleeves. Since by cutting off the light we deprive the Rhubarb and the Kale of their capacity to form food, they must perforce depend on the supply already present in the roots, so that each forcing crown must have one or more years' rest to replenish the supply before it is again utilised for forcing. The Celery and the Cardoon depend upon the free tops of their leaves to make the requisite food material for growth, so they must not be too tightly bunched together. In the culture of all these vegetables, shade tends to promote the vegetative growth we desire and to check the formation of flower-buds.

But the action of light and shade in the garden cannot be regarded independently of warmth and cold, since light and heat go together and the one affects the value of the other.

CHAPTER IV

COLD AND WARMTH: FROST AND FOG

*'But nipping winter and a froward spring
blasted our trees and all our summer buds
where blossoms should have yielded dainty fare.'*

ROBERT CHESTER (LATE 16TH CENTURY)

QUOTED FROM R. GUNTHER'S EARLY BRITISH BOTANISTS

BECAUSE the plants in our gardens are such a cosmopolitan assemblage we look forward with some trepidation to the gaps which winter's passage may leave, especially in the rock garden or the shrubbery. There we are apt to be more venturesome in our planting than in the herbaceous border, and the perennial overground shoots of most shrubs and alpine render them more susceptible to sudden changes in the weather. But nothing is really more surprising than the small number of such casualties when we think of the variety of climes from which our plants have come. Some we know must be grown in the hothouse, others will survive the shelter of a cold frame; others will endure severe cold, but there are many which we know to be half-hardy and liable to be cut back by frost, yet which, because of their beauty, we cannot forego. The Climbing Potato (*Solanum jasminoides*) that festoons the cottage roofs in the west of England with its clusters of snow-white blossoms maintains but a precarious tenure in midland gardens, though we can no more resist attempting its culture than we can resist planting the Tree Poppy (*Romneya*) or the Fuchsia Gooseberry in the hope that by a suitable soil and shelter we can cheat the elements of their prey.

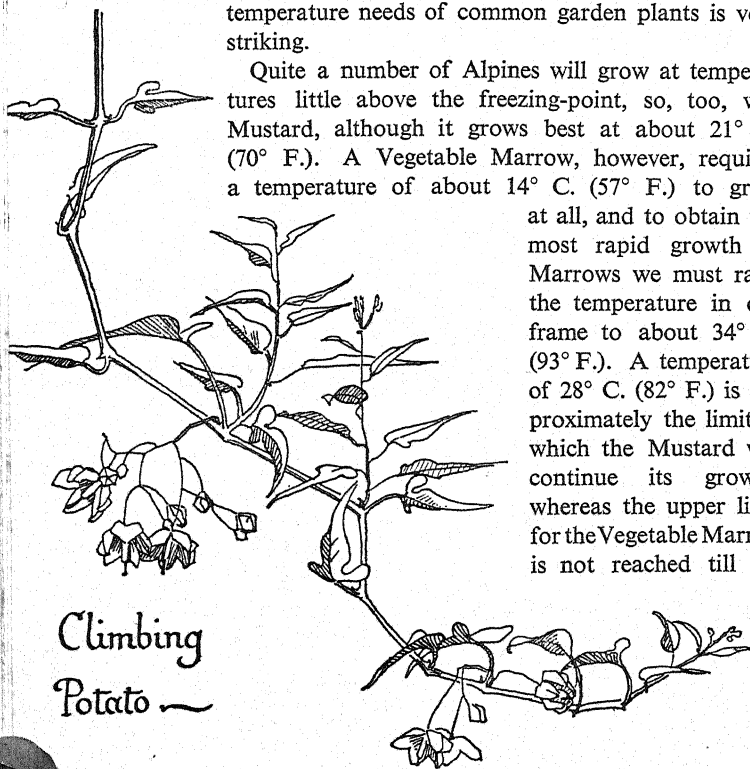
It is probable that every stage in the maturation of the plant has a temperature which is best suited to growth and development. The higher the temperature the more rapid will be the rate of chemical change—in general, becoming doubled for every rise of ten degrees centigrade. But an increased rate of chemical

change, whilst it may be beneficial to one process going on in the plant, may be undesirable in another, so that when we speak of an optimum temperature for any one kind of plant we must remember that this represents a kind of average for all the processes that go on in the living cells at a particular state of their development. None the less for these limitations, we know that to grow some plants we shall require a hothouse, whilst others will only flourish in cool situations.

The diversity in capacity for endurance of extremes is perhaps as striking a feature of some plants as the narrow temperature ranges tolerated by others. The Siberian Larch grows where the temperature for weeks may be -70° C., whilst there are certain blue-green water weeds which normally exist in the waters of hot springs. But, apart from such extremes of tolerance that suggest some special constitution, the different temperature needs of common garden plants is very striking.

Quite a number of Alpines will grow at temperatures little above the freezing-point, so, too, will Mustard, although it grows best at about 21° C. (70° F.). A Vegetable Marrow, however, requires a temperature of about 14° C. (57° F.) to grow

at all, and to obtain the most rapid growth of Marrows we must raise the temperature in our frame to about 34° C. (93° F.). A temperature of 28° C. (82° F.) is approximately the limit at which the Mustard will continue its growth, whereas the upper limit for the Vegetable Marrow is not reached till the



Climbing
Potato ~

temperature rises to about 46° C. (115° F.), and a Prickly Pear will continue to grow in a house heated to over 56° C. (133° F.).

But, though the upper limits of temperature at which different garden plants can grow are of theoretical interest, they are not so often of practical significance as are the lower limits which they can endure. The capacity of living plant tissues to survive heat has, however, recently become of practical importance owing to the adoption of hot-water treatment for the control of certain plant diseases. The efficacy of the method depends upon the greater tolerance of heat by the diseased plant than by the parasite that is attacking it. As a consequence, the treatment is often near the limit which the plants can endure, so that a knowledge of what temperature they can survive becomes essential.

The hot-water treatment of Daffodil bulbs infected by eel-worm is a familiar example. The standard method is to immerse the bulbs in water which is maintained for three hours at a temperature of 110° F. (43° C.), when the bulb is in its most dormant condition, afterwards permitting them to cool gradually. If the temperature mentioned is exceeded, or the bulbs are not sufficiently ripened, or have started into activity, the flowers will probably be injured. Properly carried out, the treatment will completely destroy the nematode worms, or any mites or fly maggots that may be present in the bulbs, but it is evident that our treatment is carried out very near the threshold of injury to the plant itself. The same method has been found efficacious for checking the all-too-familiar eel-worm pest of Phlox plants, the presence of which is marked by the narrow distorted foliage and the swollen or split bases of the stems.

The gardener's interest in higher temperatures is, however, mainly due to their acceleration of the chemical and physiological processes of the plant whereby he is able to 'force' his blooms into flower, or his fruits into production, before their normal season. But the experienced craftsman knows that the efficacy of the rise in temperature is dependent upon other conditions being adequate. As the plants in the hothouse are working at

higher speed than in the cool, they are consuming more oxygen in their breathing process, so that ventilation must be more carefully looked after than in an unheated house. The higher rate of food production, together with the higher rate of evaporation, will involve a greater consumption of water. In other words, the best results can only be attained if we ensure that all the requirements of the plants we are forcing are supplied adequately for the increased rate of consumption which the higher temperature involves. As the glass of a greenhouse cuts off much of the light, this is often the limiting factor during the winter months.

More often the question of temperature in the gardener's mind is associated with injury by varying degrees of cold. The capacity of a plant to tolerate frost is generally greater as the water which its living parts contain diminishes. What we should term dry seeds, for example, which actually contain water corresponding in amount to about a tenth of their total weight, will survive extreme frost, and even immersion in boiling water, but the same seeds after they had absorbed water would be quickly killed by similar treatments.

The greater frost tolerance of the mature shoots of fruit-trees as compared with the recently formed and more 'sappy' growths is a familiar instance of the greater susceptibility to injury from frost of those parts containing most water. This is the main reason why the new shoots formed in spring are so liable to injury by late frosts, whereas the older twigs on the same tree are unharmed. Such 'frost-bite' is sometimes seen on Walnut-trees, and emphasises the advantage of varieties which are naturally late coming into leaf.

The amount of water that a plant contains, and therefore in some measure its tolerance of frost, is a quality of the species or variety. But the proportion of moisture in a particular kind of plant may vary within certain limits. The soil in which we grow our plants has an appreciable influence on this quality. Half-hardy shrubs will sometimes endure severe frosts on a well-drained sandy soil that is dry in winter, whereas similar specimens grown on a clay soil will perish. It is not unreasonable to

suppose that this may be due to the fact that on the drier soil the shrub itself tends to be drier too. Nevertheless a wind, although it tends to dry the tissues of the plant and consequently to lower the content of water, far from being beneficial accentuates the effect of a frost.

It is noteworthy that most of the succulents we cultivate—the Cactaceae from the Mexican deserts; the succulent Euphorbias, Stapelias, Gasterias, and Haworthias from South Africa—are warm-climate plants. But the fact that a few succulents, such as the Oyster Plant (*Mertensia maritima*) and some Sedums, can endure considerable frost shows us that water content alone is not the only deciding factor in the frost resistance of the plant.

The hardy Palm *Trachycarpus Fortunei* (*Chamaerops excelsa*), an introduction from Japan in 1836, represents a family that is essentially a tropical one, and, indeed, when first introduced this particular representative was supposed to be tender. In the early years of its growth, in this country, it requires protection, but this can be dispensed with when maturity is attained, at which stage this Palm will withstand over 30° F. of frost. So, too, the Southern Beech *Nothofagus obliqua*, though quite hardy when mature, may be killed by our winters when only a few years old. Young Walnut-trees have been known to be killed outright by a frost that only injured the new growths of adult trees of the same variety growing in the same orchard.

Why frost resistance should increase with age till the plant becomes adult, one cannot as yet determine, but it is, of course, analogous to human experience that early youth and old age are periods of greater susceptibility than the prime of life, and, indeed, it has been found that not only are young trees more liable to frost injury than trees which are adult, but aged Apple-trees, as also those which have suffered from bearing an exceptionally heavy crop of fruit, are more liable to injury by frost than those trees which are in their prime or those which have borne a normal crop.

Different varieties of the same species may be very different with respect to their tolerance of frost. In the severe spring of 1917 the common Gorse (*Ulex Europaeus*), in a few instances,

suffered serious injury, whilst for most individuals injury, if it occurred, was slight; on the other hand the double-flowered variety was killed outright in several gardens.

Chemical analyses of hardy winter wheats have shown that the degree of tolerance for cold goes hand in hand with the sugar content of the cell sap, and, as it is known that with an increased content of sugar the proteins become less liable to coagulation by freezing, it is not unreasonable to regard such coagulation as a probable cause of death. Other substances besides sugars can exert a protective action of this nature. The frost resistance of Apple shoots, Cabbages and Lettuce has been found to be the greatest in those varieties in which the content of the gummy substances known as pentosans is highest, whilst in some plants immunity from cold is associated with an increased acidity of the cell sap.

These facts have a practical importance for the gardener, since the character of the cell contents can be to some extent modified and the frost resistance increased by subjecting the plants to a moderately low temperature. If plants that have been grown in a warm house are placed for several weeks in a temperature only slightly above freezing their sugar content increases and they are rendered more resistant to frost. The practical gardener had long since found empirically the value of 'hardening off' the plants that he transfers from warm to colder conditions, but the mechanism of the process has only recently been discovered.

We see, then, that there is a certain degree of adjustment possible whereby the plant becomes capable of withstanding the vicissitudes of the seasons. Some evergreen conifers which can withstand thirty or forty degrees of frost during the winter will succumb to less than ten degrees in the summer months. So, too, a late frost may be fatal to a plant that has withstood the rigours of a severe winter. A mild spell during the winter may, indeed, reduce frost resistance just as effectively as a moderately cold spell will increase it.

- That plants of warm climates can become acclimatised to cold ones has long been a popular belief, based probably on the

fact that certain introductions, which when first brought to this country were treated as tender, were later found to be quite hardy. This was true of the Hardy Palm and the Tulip-tree, but there is no ground for believing that they were not as hardy when first introduced into England as they were actually found to be later on.

There is, on the other hand, a considerable amount of data available to indicate that plants do not become acclimatised in respect to temperature even after a prolonged period. Amongst the shrubs introduced into England in Tudor times were the Bay Laurel, the White Jasmine, the Sage-leaved Sun Rose (*Cistus salvifolius*), the Spanish Broom (*Spartium junceum*), yet, despite their sojourn with us of nearly four hundred years, they still retain their half-hardy character. The Trumpet Flower (*Tecoma radicans*), the Strawberry-tree (*Arbutus Unedo*), the Portugal Laurel (*Prunus lusitanicus*), the Mediterranean Heath (*Erica mediterranea*), and the Blue Passion Flower (*Passiflora coerulea*) are all plants that have been cultivated in our gardens since the seventeenth century, yet they are still liable to be severely injured, or even killed, by a prolonged frost such as that of the winter of 1916-17.

Experiments have been carried out on pure strains of various vegetables in which the parent plants were grown under cold conditions. These experiments gave no indication of any inheritance by the offspring of the increased resistance induced in their parents. On the other hand an investigator who grew Cress plants for two generations in cold conditions obtained offspring for six succeeding generations which it was claimed exhibited an increased resistance to frost. As, however, the original stock may not have been a pure strain, the results may have been due to selection rather than to acclimatisation.

Though the evidence available thus seems to indicate that acclimatisation occurs so rarely, if at all, as to have no practical significance, the fact that different varieties or strains of the same species may differ markedly in their resistance to adverse climatic conditions shows the practical importance of selecting our plants from this point of view. It is for this reason that collectors

obtain seed from individuals of a species growing at high altitudes even though better specimens may be growing at lower levels. It is for this reason, too, that the repeated reintroduction of species from different areas is desirable quite apart from the possible value of different strains for purposes of hybridisation.

In trying to understand why some of our plants perish during a frost and others survive, we are sometimes apt to overlook the very marked differences in temperature in different parts of a garden. As the air cools down at night it becomes heavier. It is, of course, for this reason that the temperature is lowest near the ground. Actually the lowest temperatures are usually about five millimetres above the ground surface, for in severe weather the ground at a short distance below the surface is appreciably warmer than the air above, so that the uppermost layers of the soil give up a little heat to the air in contact with it. But this very slight rise of temperature close to the ground has little, if any, practical significance, except perhaps for tender seedlings raised in the open and exposed to late frosts.

Owing to the heavier character of cooling air, cold air tends to flow down any slope in the contour of the ground and collect, like water, in any depressions of the surface. So we find that a half-hardy plant growing in an apparently sheltered hollow may be badly cut back by frost when another individual of the same species in a more open exposed situation in our garden escapes unharmed. Such 'cold-air drainage' plays a very important part in gardens with sloping or uneven surfaces, and care should always be taken to ensure that all but the most robust species are so situated that any cold air draining towards them will flow away to a lower level. Even the few inches difference in soil height due to a raised bed or to planting on a slight mound may be of considerable importance in saving a tender type from the effects of a late frost.

A striking effect of the heavier nature of cold air was exhibited in some gardens after the disastrous frost of May 17th, 1935. All the gooseberries on the lower parts of the bushes were injured and turned brown, whereas the gooseberries on the topmost shoots were unharmed and bright green.

As we know, the most severe frosts usually occur on clear nights, owing to the free and unchecked radiation from the earth's surface. Similarly radiation occurs from the surface of the plant which is hindered by any screen between the plant's radiating surface and the cold air above. The practice of using smoky kerosene lamps in fruit orchards has been found an efficacious means of preventing blossom injury by late frosts, since the smoke cloud thus produced sufficiently retards the upward radiation. It is mainly for this reason that quite light coverings of bracken fronds, etc., over half-hardy plants will often prevent injury, though the shelter from the wind also diminishes the loss of heat by radiation. Loudon, writing more than a hundred years ago, records how a cambric handkerchief, supported on four stakes six inches above a patch of grass, resulted in the temperature of the sheltered area being from 8° to 11° warmer than the unsheltered patch of lawn, despite the fact that the conditions gave a negligible degree of shelter from the wind.

The effect of a wind frost is probably partly due to rapid drying of the plant, partly to the more rapid loss of heat by radiation. It may here be emphasised that solid wind-breaks, unless very close to the plants to be sheltered, are often far less effective than partially permeable ones. The former deflect the moving air current upwards, which descends again on the other side, whereas the permeable wind-break allows the air current to pass through, but the condition of turbulence which results greatly diminishes the wind velocity. Hence we can understand why it is that even wire-netting has quite a marked shelter effect, though the actual solid surface of wire it presents is, in the case of stout one-inch mesh, less than 10 per cent of the whole area.

The bent form which trees assume in windswept situations, that Richard Jefferies so aptly described as having an outline like the flame of a candle in a draught, is not, as he and many others have supposed, a mere mechanical effect, but chiefly due to wind-trimming. The buds and young shoots which are formed on the exposed side of the tree become dried up and are shed, whereas those on the lee side develop so long as they do not

extend appreciably beyond the shelter of the pre-existing branch-system. So the crown enlarges in the direction of the prevailing winds with a sloping top that creeps up gradually from the windward.

The striking examples of such wind-pruning which we see on our coasts and at high elevations on our mountain slopes are witness to the importance of wind action and show us the un-wisdom of cutting down the old stems of our herbaceous perennials too soon, unless our gardens be sheltered. The dead stems and leaves form a natural protection for the emerging shoots against the icy winds of winter. Cutting off the dead stems to within a few inches of the ground is an unsatisfactory compromise, since the interference with air movement is greatly reduced by shortening them. The fallen leaves collected between the stem bases, which add materially to the protection, are very liable to be removed if the stems be cut off.

Air movement increases with height above the ground, so that the lower the growth the less its exposure. The higher the level of the foliage the greater the wind movement, and therefore the drying action, to which it is subjected, also the further the plant has to convey water to meet this loss from its surface. The more the dead stems project above the living shoots the more the movement of the air around them will be checked and water loss from the plant correspondingly reduced.

Winds, especially if cold ones, may also be harmful in another way by preventing fruit formation, either through shrivelling up the essential parts of the flowers or by checking the movement of pollinating insects.

It is probable that cold causes death by coagulation of the living protoplasm, but this is brought about in various ways. When a plant is frozen, the water which the cells contain may be frozen out as crystals in the spaces between the cells. This results in a drying-out of the living substance of the plant. Now some plants are very tolerant of such drying. If we take a tuft of moss from an old sunny wall in the height of summer, we shall probably find that it is so dry we can crumble it up into powder, and yet if we take another similar piece and soak it in water it

will begin to grow, showing that its extreme desiccation has not killed it. At the other extreme there are many kinds of plants that are very intolerant of drying and can only survive so long as they contain an appreciable amount of moisture. Many evergreens are liable to injury if the amount of water they contain becomes very low. It is perhaps mainly for this reason that so many evergreens are susceptible to frost, particularly if accompanied by wind. Unlike the tree or shrub which sheds its leaves, evergreens retain a considerable evaporating surface throughout the year. A combination of frost and wind increases the loss from the leaves and shoots, whilst the low temperature, or frozen condition of the soil, prevents the roots from making good the loss by rapid absorption. A wind frost accompanied by sunshine is even more dangerous, because long before the warming influence of the sun's rays has had any appreciable effect upon the soil the rate of evaporation from the leaves has been accelerated.

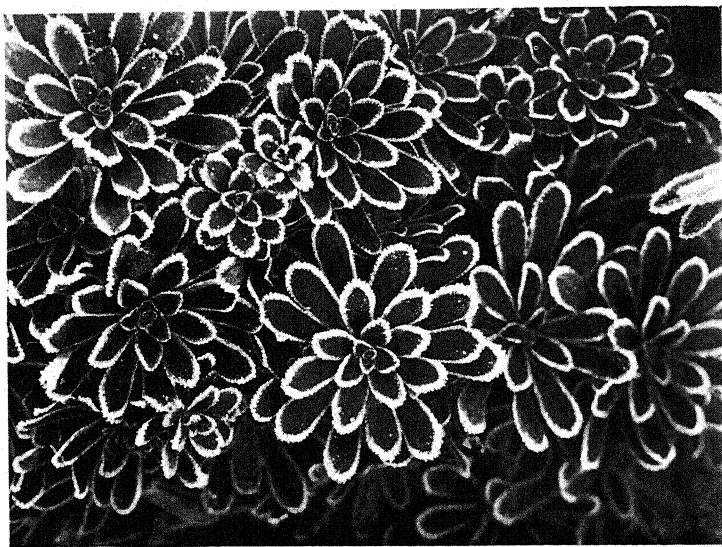
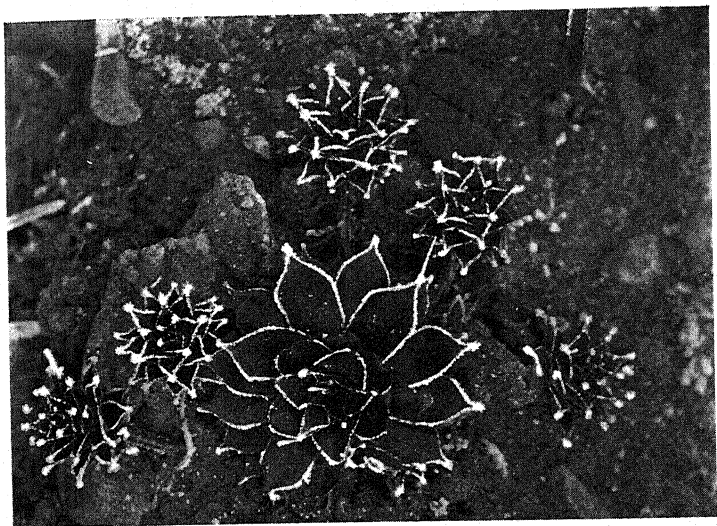
Repeated freezing and thawing may be fatal to plants which can survive continuous frost. Christmas Roses (*Helleborus niger*), which are South European woodland plants, will withstand a spell of frost with temperatures of 20° F., but succumb to seven degrees of frost if thawed repeatedly. Spring Snowflakes (*Leucojum vernal*) which came into flower precociously in the writer's sunk garden during a cold spell were quite unharmed by the frost until after a few days of exceptionally mild weather. This was followed by a frost no more severe than the ones previously experienced, but the effect was to kill the tips of most of the leaves and to injure severely many of the flowers. A more striking instance was afforded by a southern plant *Lotus angustissimus*. Plants which germinated in the autumn unexpectedly survived several sharp frosts, during one of which the temperature fell to 22° F. But even after this there was not the slightest sign of injury. A few weeks later mild conditions obtained for a short period, followed by a night frost when the temperature fell to 30° F. To my surprise the *Lotus* succumbed to the two degrees of frost when it had previously survived, uninjured, ten degrees of frost.

We are clearly concerned here with a process, in the reverse sense, similar to the hardening effect of a period of moderately cold weather, to which we have already referred. But careful notes on frost injury, particularly in gardens where meteorological data are systematically recorded, might do much to extend our admittedly meagre knowledge of this phenomenon. It is, for instance, very probable that just as the susceptibility of Narcissus bulbs to injury by hot-water treatment varies with the season of the year at which the so-called 'resting' bulbs are treated, so, too, the response to 'hardening' by cold conditions or 'de-hardening' by mild conditions may vary with the time of the year at which the temperature fluctuations are applied.

It is only by the observations of gardeners, on the one hand, and by critical experiments in the laboratory, on the other, that we can hope to solve the intricate problems connected with the temperature relations of various species as they are affected by the age and state of the plant and by the soil and other conditions of growth. Still the practical point that emerges from our present knowledge is that it may be well worth the trouble to afford protection to half-hardy species late on in the resting season.

The process of 'forcing' is naturally associated in one's mind with temperature fluctuations, and one of the commercial methods of forcing is, in fact, to subject the plants to a low temperature for a period, followed by their transfer to a warm house. In nature the occurrence of severe frost will often have the effect of bringing about an earlier development in the spring. In the forcing of Lilac, it was soon discovered that the period of rest was divisible into three parts. While the buds which are destined to expand normally in the following year are being formed in the summer they can be induced to continue their development by appropriate forcing methods. So, too, and even more readily, we can force Lilac into early bloom during the months of November and December. But the intervening period, from the end of August to the end of October, is one during which the application of forcing methods is almost without effect. With most plants the period of rest can be

PLATE III



HOAR FROST
on rosettes of (*above*) *Sempervivum*, (*below*) *Saxifrage* [$\times \frac{1}{2}$]

PLATE IV



DROPS OF WATER EXUDED FROM WATER-PORES OF POTERIUM
Photographed at 4 a.m.

broken by suitable means from the beginning of January, and with increasing ease as the season progresses.

There is clearly, then, some internal change which determines the capacity of the plant to respond to external conditions. In nature the chief factor tending to cause an abbreviation of the winter rest is the cold spell, but it is evident from what has been already said that the period at which the frost occurs will greatly influence the effect it has upon the vegetation.

Artificial forcing methods which have been successfully employed are extraordinarily varied, and sometimes unexpected. Ether and chloroform vapour were found to be just as effective prior to transference to the forcing-house as low temperature. The fact that these vapours were both anaesthetics suggested to the earlier plant physiologists that their effect, and that of freezing also, was to intensify the rest period, and hence the possibility of its curtailment. But when it was discovered, later, that buds subjected to such varied chemical substances as acetylene gas, tobacco smoke, cyanide of potassium, and even sulphuric acid, responded by earlier development, such a simple explanation appeared unlikely. Even treatment of the buds by hot water will suffice, and pricking the buds, squeezing them, treatment with an electric current, even violently shaking them, may induce precocious development.

There seems little in common amongst this diversity of methods except the fact that treatments have to be applied almost to the verge of injury in order to attain the desired effect. That the effects may be very localised is shown by experiments in which individual buds on a resting branch were immersed in hot water, and later these buds expanded into leaf whilst the untreated buds on the same branch still remained dormant. The precocious expansion of buds on the side of a tree close to an electric arc-lamp, to be observed in some streets, is probably a similarly localised effect of the ultra-violet light rays.

It is evident that the term 'forcing' is a rather inappropriate one, since we only hasten the normal sequence of events and can scarcely, if at all, break the main period of rest once it has been entered upon. Even 'forcing' of buds before they pass into this

immobile mid-rest period does sometimes occur in nature, and is, in fact, so familiar an occurrence in some trees, such as the Oak, that the precociously developed shoots have even a popular name. Such 'Lammas' shoots are occasionally produced by various trees and shrubs, and our 'forcing' processes but increase their number or bring about the phenomenon in species from which it is normally absent. The moral of all this is that the gardener must work in co-operation with the plant—leading rather than forcing; and to do this requires that he should know for each individual kind how, even when apparently resting, it changes with the cycle of the seasons.

The effect of cold is naturally also associated in the gardener's mind with the fairy-like appearance of his shrubs and trees crusted with hoar-frost, outlining the Holly leaves with a rim of silver, or encrusting the tracery of the Birch twigs with a frill of rime. This is a visual witness to the lower temperature of the leaves and twigs compared with that of the surrounding air. It is true that the parts of plants above the ground are approximately at air temperature, but they consist in great part of living cells which are respiring, and thus producing heat. Hence we do in fact find that even in winter, when respiration is at its slowest, the parts of the plant which are most active tend to be at a slightly higher temperature than, for instance, the dead cells of the bark, or the strengthening tissues and dead elements which, in large part, form the veins and midribs of a leaf, or in the Holly form the thickened margin of the leaf blades.

So, too, the hairs which cover many leaves are often dead structures filled with air, from whence comes their white appearance. It is because they are dead, or at least very inactive, that such tissues are the coldest parts of the plant, and so are the first upon which moisture from the air condenses, either in the form of dew or hoar-frost according to the temperature. Thus it is that the Holly leaves are edged with rime as though the dark green blades had been painted round with a magic brush, the hairs upon the Brambles stand out white against the painted background of the autumn colouring, the awns of the dead grasses are bespangled with glistening crystals and the rosettes

of the Saxifrages and Sempervivums are edged and tipped by hoar-frost.

On a summer evening when the air is warm the leaves are at a lower temperature than the air, owing to the cooling effect of the evaporation from the leaf surface, and so moisture condenses on the leaf as dew. This dew may be, to a very limited extent, absorbed through the surface, though very slowly, since the covering of the leaf is not readily permeable to water vapour. Still this deposition may be important, since loss of water from the leaf is at a standstill, and there may even be a slight gain of water—all of which enables the absorption by the root to make good any deficit due to the rate of evaporation from the leaves during the daytime being faster than the rate of intake by the roots.

If, however, the soil be wet, as from a heavy shower of rain in the night, there may be an excess of water taken in by the plant, and then the dew upon the leaves is a hindrance to getting rid of the excess by evaporation. Under these circumstances there come into action certain safety-valves, known as water-pores, situated at the leaf tip—or, very commonly, at the tips of the teeth upon the leaf margin.

When the water within the plant reaches a certain pressure it is forced through certain tortuous and very narrow channels between the cells situated over the vein endings, and exudes through water-pores which are modified stomata. If the air is not saturated with moisture the water that passes out will most probably evaporate as quickly as it exudes, so that there is no visible sign of what is happening. During the daytime this is most commonly the condition. But if the air is saturated with moisture, as it not infrequently is at night, the exuded water collects over the water-pores as little drops of liquid, so that sometimes the leaf teeth are beset with drops like an edging of pearls around the blade. It is these drops that may frequently be seen in the early morning before sunrise, especially at the tips of the grass blades, and are popularly referred to as dew-drops.

On the other hand, on a hot summer's day we are often

confronted with the flaccid appearance of our plants, due to a deficiency of water. Although the plant is absorbing water by its roots, it is losing it still more rapidly from its leaves. The water in the stem of a plant is being sucked upwards and if, under these conditions, we cut off flowers, air instead of water is sucked into the flower stalks: so that when we place them in vases the water-pipes are clogged with air bubbles, and sooner or later the flowers begin visibly to wilt. By slitting up the stems, or by placing the cut ends in warm water, so as to cause expansion, we may displace the air bubbles, and thus enable the plant to take in the necessary water again to make good its losses.

The withering of cut flowers after they have been kept in water for some days may occur through clogging of the water-pipes from another cause, namely, the development of bacteria upon the injured surface. By repeatedly cutting off a small portion of the end we can keep the water-pipes open. It is for this reason, too, that antiseptics in the water will sometimes enable cut flowers to remain fresh for a longer period. The belief that aspirin tablets increase longevity of cut flowers appears to be unfounded, as careful experiments give no support to the view that this has any effect in prolonging the flower's life.

Actual deposition of moisture from the air is particularly important to the gardener in the more densely populated areas and in the neighbourhood of large cities, because, together with the moisture, there are deposited the various impurities with which the coal fires and manufacturing processes have polluted the atmosphere.

Amongst these noxious products of human activities we may note that ordinary illuminating gas is decidedly poisonous to plant life. Quite low concentrations in the atmosphere are sufficiently toxic to cause abnormal growth. It is scarcely surprising to find that when gas-pipes leak into the soil the vegetation in the neighbourhood may be completely killed. This is partly owing to the displacement of the air and consequent inability of the roots to breathe. (This effect is comparable to that produced by street paving or tar-macadam, both

of which prevent downward diffusion of air so that, as the partial pressure of oxygen decreases with its utilisation by the plant, the carbon-dioxide concentration augments.) But the effect of the gas is mostly due to the toxic substances it contains. These appear to be mainly the unsaturated hydrocarbons, and their deleterious influence is especially marked upon growing parts of the plant. Ethylene is perhaps the most important of these poisonous substances, and even so slight a pollution as one part of ethylene in a million parts of air has been known to have a harmful effect.

So it is that plants in rooms or greenhouses in which gas is used often fail to grow satisfactorily, and the effect is the more marked in that a plant grown in dull light is more sensitive than the normal plant grown in the open. That no smell of gas may be detectable is no criterion of the harmlessness of the air. The human nose is rarely sensitive to concentrations lower than about one part of gas in four hundred parts of air, whereas half this concentration would contain enough ethylene to be extremely toxic. Even so small an amount of illuminating gas as one part in twenty thousand parts of air may be harmful to growth. Half this strength will kill the young buds of Carnations in three days and prevent the opening of fully mature ones.

The effect of ethylene is of particular interest as it has been shown quite recently that ripening Apples give off appreciable amounts of the gas, which has the effect of hastening the ripening process of immature fruit. Hence in Apple storage the removal of ripe fruit will promote the keeping of those Apples that remain, and this is doubtless one of the reasons why an Apple store, to be satisfactory, must be well-ventilated. Incidentally the ripening of Apples can be retarded by the use of another gas, namely carbon-dioxide. In 10 per cent of this gas, Apples and some other fruit may be kept unharmed long after their normal season.

Condensation of moisture in the atmosphere takes place particularly upon the hygroscopic crystals and other constituents of the dust. In air which is free from dust, fog only forms with difficulty, and it is this relation of fog formation to dust particles

which is chiefly responsible for the much greater frequency of fogs in cities and their environs.

In the purer air of the country the degree of supersaturation of the air with water vapour must be considerably greater before condensation takes place. When the air is uncontaminated by smoke and the volatile products of factories, etc., the moisture which condenses upon the surface of the stems and leaves of plants is usually harmless, and may, indeed, be beneficial. But in cities and their neighbourhood fogs often do considerable damage to vegetation.

It is now some forty years since Professor F. W. Oliver collected some of the deposit from a greenhouse roof in Chelsea which had formed during a period of severe fogs. This deposit he dissolved in water, and used the solution to paint one side of various leaves. The results showed clearly that the substances present in fog have a local corrosive action.

The most marked effect of fog on plants, when actual shedding of the leaves is induced, is apparently a consequence of toxic gases diffusing into the interior of the leaf and injuring the unprotected cells within. This is especially noticeable in greenhouses near towns, where the leaves of Begonias, for instance, will be caused to fall off by a fog; despite the absence of any external sign of injury. Sulphur-dioxide, a gas generated during the burning of coal fires, is probably the chief poison responsible. It is normally present in the air of towns, but only in small quantities when the air is clear. There is more when the day is dull; and when there is a yellow fog there may be sufficient to produce a gramme of sulphuric acid from every 5,000 cubic feet of air. The sulphur-dioxide gas is readily absorbed by water, and in the presence of air the aqueous solution is rapidly oxidised to sulphuric acid. So on a foggy day this very corrosive acid is being formed upon the surface of the leaf, and, what is worse, upon the surfaces of the thin-walled cells inside the leaf.

There are other poisonous substances also present in the air of cities, such as hydrochloric acid, ammonia, phenols, illuminating gas, etc., which even when present in very small quantities have an injurious effect upon plants. How deleterious the air

of cities can be for plant growth is perhaps best shown by the absence or paucity of Lichens and Liverworts on the trunks of trees near towns, and their gradual increase as we pass away, especially on the sides of the trunks sheltered from the direction of the prevailing winds. Estimates made near Stolberg, in the Rhine Province of Germany, show that there the annual deposit of sulphuric and hydrochloric acids is about 800 grammes per square metre, or not far short of one and a half pounds of acid per square yard!

If we have the misfortune to cultivate a garden in or near a city, we can minimise the effects by frequently washing the foliage of our plants and by adding lime to the soil. The acids will be removed from the one and neutralised in the other.

CHAPTER V

CONCERNING ALPINES AND ROCK PLANTS

'Experience is a name everyone gives to their mistakes.'

OSCAR WILDE

THE cult of the rock garden is quite a modern one, and this is probably due partly to the comparatively recent date of introduction of most alpine and rock plants, and even more to the fact that the technique of their successful culture has not long been understood. The vogue of the alpine owes not a little to the appeal which the miniature always has, for the alpine plant bears much the same relation to the plant of the herbaceous border as a miniature to a life-size painting. It is the same attraction that has rendered popular so many dwarf strains, such as the Tom-Thumb Nasturtiums, the dwarf Snap-dragons, the Cupid Sweet Peas, the 6-in. *Rosa Roulettii*, and divers others. But the alpine and rock plants combine with the appeal of their small size the merit of a due proportion between their parts—a quality which is often lacking in the dwarf varieties of tall species.

The low stature and often mat-like habit which are so frequent amongst these rock plants are features which we can associate with the rigour of the conditions in which alpine plants naturally grow. The green mats of the arctic and alpine Willows—such as *Salix retusa*, *Salix reticulata* and *Salix herbacea*—do not usually grow more than a few inches in height, although they may cover an area of several square yards. When these bear their miniature catkins in spring, the male plants at once remind us of our 'Pussy' Willows, and yet emphasise the striking contrast in their stature. Whereas the Willows of our swamps and woodlands grow upwards into shrubs and trees, these alpine and arctic shrubs spread horizontally. They are very slow in growth and the main stem of an individual half a century old may not be more than a quarter of an inch in thickness. We

find these mat-like shrubs forming a characteristic feature of the arctic vegetation as well as at high altitudes on mountains. *S. reticulata* and *S. herbacea* occur near the summits of some of the English and Scottish mountains, and the latter has been found in the Swiss Alps, growing at an altitude of over 11,700 feet.

No more striking instance of this mat-like growth is afforded than by the Fir *Pinus montana*, which, though it can present the normal pyramidal Fir-tree habit at lower altitudes, is found above the tree limit as a spreading mat-like bush, sometimes not more than a foot in height though many square yards in extent. So, too, in arctic regions, the Spruce Fir is sometimes found growing as a low-spreading scrub, just as the tall growing Birches and Junipers of the south are represented in the extreme north and at high elevations by the dwarf species *Betula nana* and *Juniperus nana*.

The Mountain Dryas, with its carpet of glossy evergreen leaves, from amongst which spring its cream star-like flowers in June, to be followed by the fluffy heads of plumed fruits in summer, is another instance of this prostrate shrubby habit, shared also by *Loiseleuria procumbens*, *Polygala chamaebuxus*, the Crowberry (*Empetrum nigrum*), the Bearberry (*Arctostaphylos alpina*), and many others. *Loiseleuria procumbens* is practically



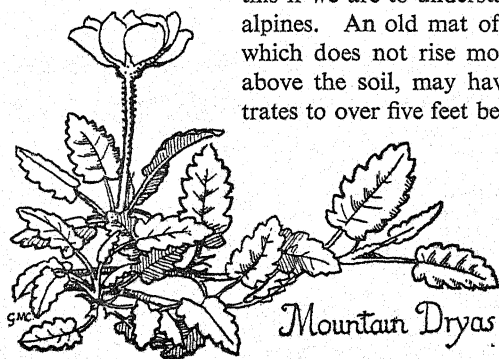
an azalea, and so emphasises the contrast with its more familiar and taller relatives.

Amongst the less woody species a similar mat-like growth is exhibited by the beautiful Moss Campion (*Silene acaulis*), the purple Saxifrage (*Saxifrage oppositifolia*), both natives of Britain, the Swiss Globularias, the dwarf Grecian Scabious, *Scabiosa pteroccephala*, or the Acaenas from New Zealand. The low habit of growth of all these plants enables them to endure exposed situations that would be impossible for taller-growing species, and the mat-like association of the shoots also confers additional protection from the effect of drying winds, besides tending to retain a covering of snow which may be essential for their welfare.

The mutual protection which the shoots afford to one another is also effectively attained by the cushion habit which we see so well exemplified in that extremely difficult, but beautiful, alpine *Eritrichium nanum*.

The characteristically low growth of the alpine is the more striking if we compare the development of the shoot system with that of the root beneath the soil. Compared with many plants the roots of the alpine species are naturally very extensive. In their mountain homes there is usually a considerable depth of rock detritus and scree in which the roots can readily find their way between the rock fragments. It is important to realise

this if we are to understand the cultivation of alpines. An old mat of *Dryas*, for instance, which does not rise more than three inches above the soil, may have a root that penetrates to over five feet below the surface.



Mountain Dryas

By means of the extensive root system a sufficient volume of soil is exploited to enable the plant to obtain an adequate amount of moisture even from

a very well-drained site. By its deep penetration the root reaches a level at which the soil is scarcely affected by the fluctuation in temperature of the surface, however hot this be, and where the supply of moisture, if low, is nevertheless constant. Many alpinists, and amongst these some of the most difficult, are thus rather nicely adjusted to a low but constant supply of moisture. So it is that we encounter the apparent contradiction that some of our choicest alpine plants get killed by drought in our hot summers, whilst if we plant them in a moister situation we find that they 'damp off' in the winter.

The moraine garden, with its considerable depth of rock fragments, is often a solution to the problem of how to cultivate difficult subjects, because it furnishes some approach to the deep, cool, but well-drained, root run of the natural habitat of these species. The moister the climate, the more one must ensure drainage in the moraine. Limestone chips, with no soil but only the limestone dust, have been found efficacious in moist areas, whereas in drier climatic districts a small proportion of soil or leaf mould is needed in addition. It is all a question of ensuring the proper balance between climate and soil so that the roots shall not be too wet in winter or after a heavy fall of rain, and yet the soil must be sufficiently retentive of moisture to prevent drought in summer. In assessing the merit of a recipe for making up the moraine 'soil' it is well to remember that organic material retains water very readily, and that any soil we incorporate is less retentive the coarser its texture. Moreover, just as wild species which are apparently indifferent to the nature of the soil on the Continent are in our damp climate restricted to the chalk, because of its physical qualities, so, too, we may find that limestone chips are a better medium for the roots of a reputed lime-hater than granite or sandstone.

If we plant alpinists in conditions where the root development is restricted because of the finer soil texture, it will involve the roots being moister. On the other hand if the poor root development is a consequence of restricted space, because there is only a small pocket in which the root can grow, we shall have to increase the water-supply to make up for the small

volume it can draw upon. In either condition the plant will be more 'sappy' and less resistant to both the drought of summer and the rigours of winter.

Many alpine, as we might expect, can survive quite low temperatures. Cushions of the Moss Campion (*Silene acaulis*) have been known to emerge unharmed from being embedded in a solid block of ice. *Sibbaldia procumbens* uncovered by snow will withstand nineteen degrees centigrade of frost. The tolerance of low temperatures is apparently connected in many of these species with a high content of sugars in the cell sap.

Nevertheless it must not be assumed that all alpine are equally immune from injury by cold, since in nature many, as already noted, escape the extreme rigours of winter under a covering of snow. This protects the plants from loss of moisture and from the wind as well as from the extreme cold. Even a comparatively thin covering of snow will protect the soil from becoming frozen by a short spell of cold, and alpine growing at high altitudes under a covering of more than a foot of snow have been found continuing their growth despite prolonged frost, amid air temperatures registering more than thirty degrees Fahrenheit of frost. It is evident, then, that because a plant grows wild at a height of 6,500 ft. above sea-level it will not necessarily endure a lowland station where it is fully exposed to the direct effects of wind and cold. Still, most of the leathery-leaved mat-plants, such as *Thlaspi rotundifolium*, *Saxifraga aizoon*, *Dryas octopetala*, and the evergreen shrubby species, such as *Polygala chamaebuxus* and *Erica carnea*, endure severe frost without any protection.

Just as many alpine are very intolerant of the drought of summer, so, too, they are susceptible to the cold winds in winter. The frozen soil cuts off the supply of moisture from below, whilst the rapid movement of the air above hastens the loss of water from the leaves. The hairiness of the foliage of the Edelweiss, the Androsaces, the Antennarias; the brown scales of the leaves of the alpine Rose (*Rhododendron ferrugineum*) and the tufted habit of *Saxifraga burseriana*, and many others, afford a certain measure of protection against such desiccation. It is

this risk which necessitates, and, indeed, in part imposes, a dwarf habit on the plants of alpine situations.

Many years ago the French botanist Bonnier divided a number of plants, and grew portions of the same individuals in both alpine and lowland situations. The plants grown at the higher elevations were always shorter, and in some instances only a tenth the height of their lowland twins, but the roots were not dwarfed to the same extent; so that the absorbing surface is relatively greater in the alpine station. The flowers in relation to the size of the plant are also large, and may even be bigger than those of the lowland individuals.

The horticulturist is naturally more interested in what happens when we cultivate the alpine plant in the lowland. The effect is somewhat the reverse of growing a lowland plant at high altitudes, but fortunately, as we know, many alpenes retain their low growth, and to some extent their free-flowering, in our lowland gardens. But there is the tendency to lose the dwarf habit and to grow in a straggly manner, which is accompanied by a more rapid and succulent growth. Starch may be formed instead of sugars, and the total outcome is a lower resistance to extremes of either drought or cold.

The charming little silvery cushions of *Potentilla nitida* become loose and straggly upon good soil, and we may very probably lose our plants in winter; even if they survive, there will almost certainly be no flowers. But if we grow the same species upon the poorest of dry sandy soils, in full sun, it will maintain its dwarf character, and will not only persist, but flower freely.

We must, in fact, beware of treating our alpenes too well. A rapidly growing *Saponaria ocymoides* may give us an extensive carpet of pink blossom for a brief season, but its slower-growing brothers are the more likely to endure and persist.

The intense coloration of *Gentiana bavarica* and *Arnica montana*, of *Senecio abrotanifolius* and *Sieversia reptans*, as we see them growing in their alpine homes, cannot be emulated in the lowlands, for this is connected with the conditions of illumination which it is as yet impossible to imitate—though

what the alpine house of the future may effect, artificially lighted with ultra-violet lamps, it would be rash to prophesy.

The colour of our lowland plants would perhaps look a trifle more intense if we carried them up with us into the mountains and saw them in the alpine daylight, which is appreciably richer in the shorter wave-lengths; but the alpine flowers not only look, but are, better coloured than those of the same species grown at low levels. The cultivation of alpins is a continual experiment in which we must try, by adjustment of soil texture, drainage, and situation, to provide a compensation for the inevitable defects in the climatic conditions that are beyond our control.

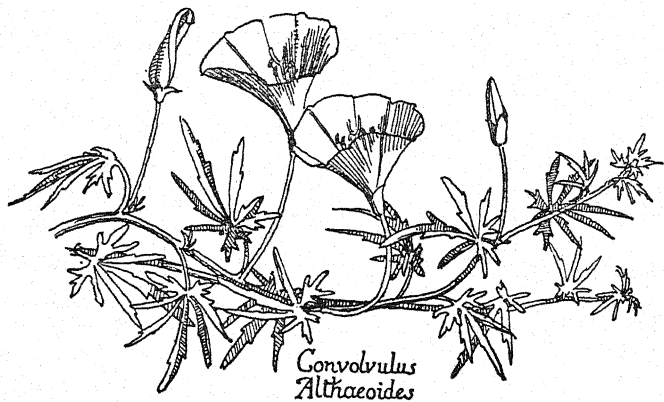
Experiments have been carried out with alpins in which different series of the plants were respectively watered with ordinary water, water from condensed steam and water from melted ice. There is some reason for believing that the physical nature of the water obtained in these three different ways is not identical. It is therefore of some interest that the plants watered with melted ice appeared to flourish best, and this gives some support to the view that the luxuriance of some species, such as *Sieversia reptans*, when growing on the morainic deltas in the Alps may be due to the glacier water with which they are irrigated. This has nothing to do with the so-called 'Heavy water' of which so much has been heard recently. Heavy water, in which the hydrogen atom of ordinary water is replaced by an hydrogen atom of twice the normal mass, is, so far as at present known, deleterious rather than beneficial to plant life, but as it is usually present in water in the proportion of only one part in 6,500 its effect may be entirely negligible, though the beneficial effects of minute traces of Boron, Nickel, etc., upon plants, or of vitamins in animal nutrition, show how rash it would be to assume unimportance for any substance just because it is in low concentration.

It is well to remember, however, that not all the plants we grow in our rock gardens are alpins, and some may require very different treatment. The Hedgehog Broom (*Erinacea pungens*), for instance, is a native of rocky places in Spain, and will endure

the sunniest situations and the driest of soils. At the other extreme *Salix herbacea*, an arctic-alpine, which is at home in the little hollows at high levels where the snow remains late into the year, will tolerate a soil that is waterlogged for some months.

Very few true alpine are annuals (*Gentiana nivalis* is one of these few exceptions), and biennials, such as *Campanula thyrsoidea*, are equally uncommon. Nearly all alpine are evergreen perennials. This characteristic is scarcely surprising, as in their native home the period for which they are uncovered by snow is very limited—sometimes less than seven weeks, and rarely more than three months. It is evident, then, that any plant which is to survive under these restricted conditions of illumination must be able to make the most of the short period when the snow has gone and the temperature is sufficiently high to enable the leaves to use the light for the manufacture of food. Evidently, under such conditions, the annual plant, or a perennial that has shed its leaves, will be at a disadvantage, since some of this all-too-short growing season will be spent in the formation of new leaves before any food manufacture can begin. The evergreen can start work right away directly the snow covering has melted. Indeed, actually the evergreen may start making food sooner than this, because sufficient light penetrates through the snow when the covering is only a thin one, and many high alpine can make food at a lower temperature than most low-land plants. Some can even show a balance of production over expenditure when the temperature of the surrounding air is nearly 30° F. below the freezing point. In this, alpine are no doubt assisted by the dark colour of their foliage and the clear atmosphere, which combine to enable the leaves to absorb radiant energy from the sun, an appreciable proportion of which perhaps serves to raise the internal temperature of the leaf to the necessary level. Some of the heat produced by respiration is probably also used in this way, for it is evident, by the way in which, for instance, the flowers of a *Soldanella* melt their way through the covering of snow, that some alpine produce a considerable amount of internal heat.

Because the plants we cultivate in a rock garden are chiefly those of low growth, they are the more susceptible to the effects of competition from taller and more vigorous species, and we must therefore beware of introducing rampant growers such as *Convolvulus Althaeoides*, *Euphorbia cyparissias*, *Acaena Buchananii*, *Campanula pusilla*, *C. rapunculoides*, *Physalis*



alkekengi, *Vinca minor*, etc. Even plants which seed freely may be a danger in proximity to the moraine.

The open character of the vegetation that must be maintained if we are to ensure success nevertheless renders the rock garden peculiarly suited to learning about the habits of the plants we tend. We can readily note when the self-sown seeds germinate; on what soils they will grow; how soon they flower; when they fruit; how long the plants live. But, if we would really learn the habits of our plants, we must not trust to memory but keep exact notes of what we see. Such notes become more valuable as they accumulate, and one always finds that, however apparently complete, there is always something one wishes had been more fully recorded. So do not be afraid of recording too much, for you will always record too little. It is often only when the hot summer is past that one realises how interesting it would have been to know just how dry the soil was, and what

temperature it attained, or, after a hard frost, how deeply the soil was frozen which killed some of your treasures and left others to survive. Of those who rear and maintain the more difficult alpine, few can recall the exact treatments they adopted for success, and still fewer the precise conditions that led to their failures. Yet the failures may be as important as the successes if our garden-craft is to be something more than a mere technological achievement.

CHAPTER VI

THE GARDEN UNDER THE SOIL

'They are ill discoverers that think there is no land, when they can see nothing but sea.'

BACON. ADVANCEMENT OF LEARNING

THE TRACERY of branch and bough above ground is familiar enough, so too the leafy shoots of herbaceous plants, but the tangle of growth beneath the surface of the ground is hidden from our sight. If we could remove all the soil, yet leaving the root systems of our plants in position, we should soon realise how great the variety in their branching, their extent, and their mode of occupation of the soil.

These roots fulfil two main purposes: as an anchorage for the plant to the soil and as an absorbing organ for the water, and the dissolved substances in that water, which the soil supplies.

It is evident that the more extensive the root becomes the larger will be the absorbing surface which it forms in contact with the soil particles; so that, unless the soil be very moist, the plant will obtain more water the larger and more richly branched its root system is. If the soil be very wet, then the extent of the root may not affect the water-supply to the leaves, since under these circumstances the rate of flow will depend on the size of the water tubes in the stem.

The roots and the stem, as well as its branches, contain water-pipes by means of which the watery solution taken up from the soil is conveyed to the leaves and growing parts of the plant. Here the dissolved substances, together with some of the water, are mostly used in the building of the plant's body. Part of the water absorbed is also used in the manufacture of food material, but the bulk of the water is lost by evaporation from the exposed surfaces of the plant, chiefly from the leaves. To keep these leaves from becoming wilted, a constant supply of

water is essential, because the leaves only perform their chief function—that of the manufacture of food material—when they are turgid.

As the plant enlarges, the need for water becomes greater, since the evaporating surface has increased. If the plant becomes taller as it grows, the exposure to wind increases more than if the growth of the plant is mainly a spreading one at about the same level as the shoots already formed; for the latter afford shelter for the new growths.

The water-pipes in the roots, stem, and branches can thus be compared to the water-mains supplying the increasing population of a city. If there is an abundant supply of water to which the mains are connected, then the amount available for the consumers is dependent on the rate at which the water is pumped through them.

The limit to the supply in these conditions is the size of the mains and the pumping force applied; not either the number of reservoirs or the amount of water in each. Similarly, with regard to the roots of plants, when the water-supply is abundant the limit to the amount the leaves obtain is influenced by the internal structure of the stem and root, and by the number, size, and structure of the water-pipes they contain, rather than by the extent of the root system and the absorbing surface it presents to the soil. But, except in the water garden or the bog garden, such conditions of abundance seldom obtain, and usually the supply to the shoot is determined far more by the amount of moisture in the soil and by the extent of the root surface than by the internal structure of the plant.

The amount of water available may be increased in two ways. The plant may develop a root system occupying a large volume of soil, in which the number of roots, and hence the root surface, in any particular part of this soil will be small, but the root as a whole is extensive, and exploits a considerable area and depth. On the other hand, the same amount of root growth may be expended in an intensive occupation of a much smaller volume of soil, from which, however, the removal of water is much more complete. The former type is exemplified by the

root systems of the Ash-tree and Lupin, whilst the Beech-tree and the Perennial Phlox illustrate the latter.

The fact that Beech-trees are not infrequently uprooted by wind during severe storms illustrates one drawback to the intensive type of root system—namely, the less efficient anchorage it provides. At the same time the small but richly branched root system has its advantages in competition with other plants, since by complete exploitation the establishment of other plants in the same area is checked or entirely prevented. It is largely the competitive equipment of the Beech-tree, with its lacework of branches in winter, its shady canopy of foliage in summer, and its intensive root system, that accounts for the comparative scarcity of other trees and shrubs in a natural Beech forest. In contrast we may note that the natural woods of Ash-trees, with their light canopy and extensive root systems, contain a number of associated trees and a profusion of shrubs. What applies to trees in a woodland also applies to plants growing together in a garden.

Stephen Hales, in the early part of the eighteenth century, made an attempt to estimate the absorbing surface of the root system of a Sunflower plant. He found that the total length of all the roots amounted to 1,448 feet, with a surface area of nearly sixteen square feet, but only a part of this is actively taking in water. The absorbing surface of roots is considerably increased by the fact that, just behind the tips, the roots of most plants are covered by numerous hairs, which come into intimate contact with the soil particles. It has been estimated that in some plants, such as the Maize, the absorbing surface of the root may be increased as much as seven times by the presence of these root hairs.

The depth to which the roots extend is often considerably greater than we suppose, since unless great care is exercised when a plant is dug up the finer rootlets will be broken across. The roots of the Blazing Star (*Liatris pycnocephala*) in its prairie home may penetrate to a depth of sixteen feet and those of Silphium to from nine to fourteen feet. The well-known difficulty of eradicating the field Convolvulus is due not only

to the fact that it readily produces shoots from almost any part or portion of its root system, but also to the depth to which the roots may penetrate. Live roots of this weed have been found at a depth of over seven feet.

In many plants we can distinguish between the anchoring roots, which penetrate to a considerable depth, and the feeding roots, which are much more superficial in their growth. The exact depth which the root system attains for any one kind of plant will vary with the nature of the soil. A dense soil which offers considerable resistance to penetration by the roots, such as a heavy clay, involves a much greater expenditure of energy by the plant in developing an extensive root system than a light loam or sandy soil. Expenditure of energy means the using up of the plant's food material, so this alone tends to restrict the root systems on heavy soils.

Furthermore, all roots need to respire, for which access of air is essential. In this process oxygen is absorbed and carbon-dioxide evolved. The latter, being a heavy gas, tends to diffuse downwards into the spaces between the soil particles, and the same gas is also being formed in the respiring process of the multitudes of microscopic organisms which live in the soil. The soil thus has an atmosphere of its own which is much richer in carbon-dioxide than the open air we breathe, but poorer in oxygen. The looser the texture of the soil the more readily the soil atmosphere mixes with the open air above, and the difference between them is minimised, whereas in dense soils the possibility of such mixing is decreased and the difference is accentuated.

But, whether the soil be heavy or light, the composition of the soil atmosphere will be closer to that of ordinary air the nearer we are to the soil surface. Now, owing to the necessity of oxygen for the breathing of roots and the depressing effect on root growth of too high a carbon-dioxide concentration in the soil atmosphere, the conditions for root development tend to be most favourable near the surface, and to become less so with increasing depth. On the other hand, since there is evaporation from the soil surface, the moisture in the soil tends

to increase as the root grows downwards. Thus the depth to which the root system penetrates represents a compromise between the disadvantages which increased depth brings, with respect to the soil atmosphere and ease of penetration, and the advantages with respect to better water-supply.

By cultivating the soil the gardener increases the ease with which the roots can penetrate to the deeper levels, though the mere weight of the soil ensures a denser packing below of even a freshly dug piece of ground. Further, every time the soil is turned over the soil atmosphere becomes mixed with that of the surrounding air, so that in every way the conditions for greater root extension are improved.

When we dig manure into the soil, we not only add essential

food substances, but increase the capacity of the soil to retain the rainwater that falls upon it. Nevertheless, this organic material is acted upon by multitudes of bacteria, which in their turn form the food of numerous protozoa, both of which add appreciably to the carbon-dioxide production in the soil, which tends to replace the air. The less decayed the manure the more active is the decomposition and the greater the output of carbon-dioxide, and this is one of the reasons why some plants are intolerant of 'fresh' manure, because it interferes with the good aeration of the soil.

The capacity of roots to tolerate badly aerated soils varies greatly in different



From Dodoenaeus' *Herbal*, 1554

kinds of plants, some, such as many Willows, being capable of maintaining live roots in soil with very high proportions of carbonic acid gas and very low proportions of oxygen. This is true also of the Plane-tree, and to a less extent of the Lime-tree; which is one of the reasons why these trees can grow in cities, where the greater part of the soil occupied by their root systems is cut off from gaseous exchange with the atmospheric air by the flagstones of the pavement and the asphalt of the road surface.

It is not only the roots of plants which the soil conceals. Hidden underground are the rhizomes of the Lily-of-the-Valley and the Solomon's Seal, the swollen stems of the Crocus and Winter Aconite which we call corms, and the buds, consisting of leaves swollen with food material, that form the bulbs of our Hyacinths, Scillas, and Lilies.

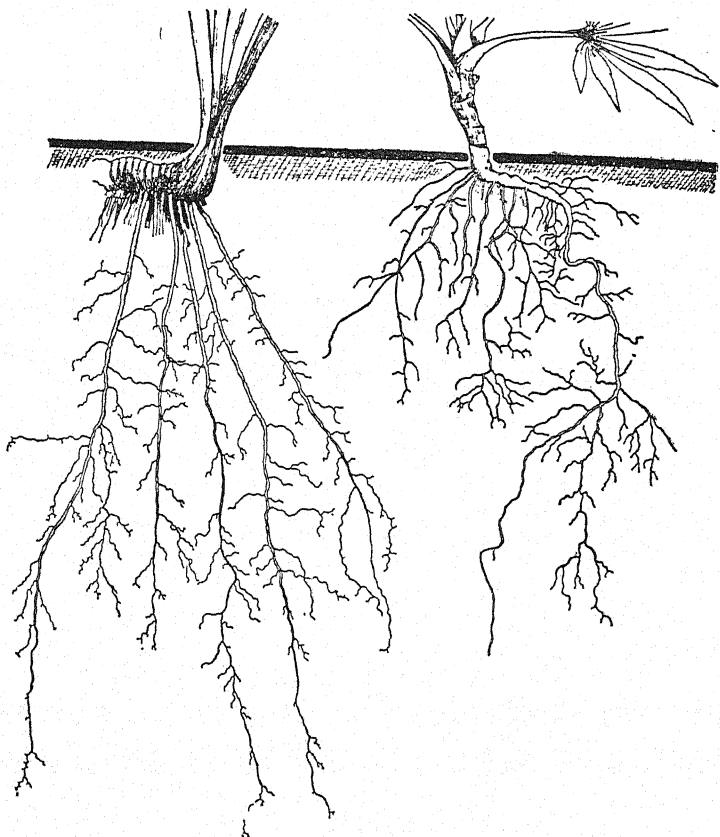
If we observe carefully the depth at which these grow, we shall find that where the soil is of a similar texture and moisture the underground stems and buds of the same kind of plant are situated at approximately the same level. In heavy soils, such as damp clays, the rhizomes, bulbs, and corms are usually nearer the surface, whilst in light soils, such as sands and loams, they grow deeper down.

But in either heavy or light soils we shall probably find that the relative depth of the underground parts of different kinds of plants are similar. Thus alike on a clayey soil or a sandy loam we shall find the rhizomes of the Solomon's Seal much deeper down than those of *Anemone apennina*. Such underground shoots have to push their way through the soil, which offers considerable resistance to their growth. If we were to dig up a block of soil and try to push a skewer into it at different depths from the surface, we should quickly realise how much easier growth must be nearer the surface than at a depth of several inches.

The rhizomes which normally grow deep down are of course better protected from frost, from abrupt changes in moisture of the soil, and from being eaten by animals. But their growth means a greater expenditure of energy as compared with the

72 THE GARDEN UNDER THE SOIL

rhizome near the surface, which can with the same output of energy extend further, and so by its more rapid spread reduce

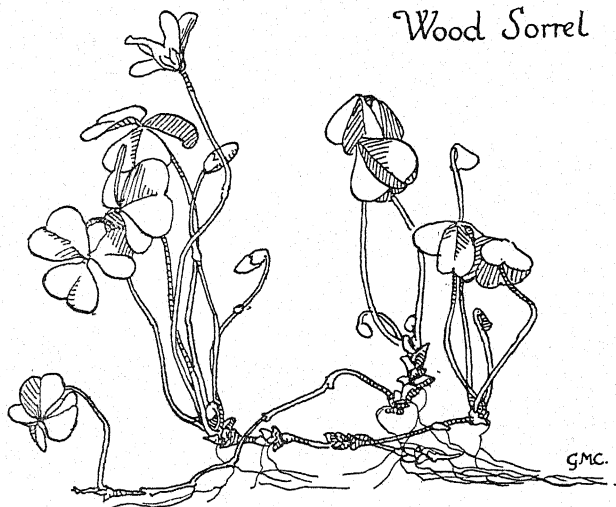


ROOT SYSTEMS of *Iris foetidissima* (left) and *Helleborus foetidus* (right)
Drawn to scale, by the author, in their natural position in the soil. [x $\frac{1}{4}$]

the competition between the different shoots of the same plant.

If we look at the rhizomes of a number of plants, it will be

Wood Sorrel

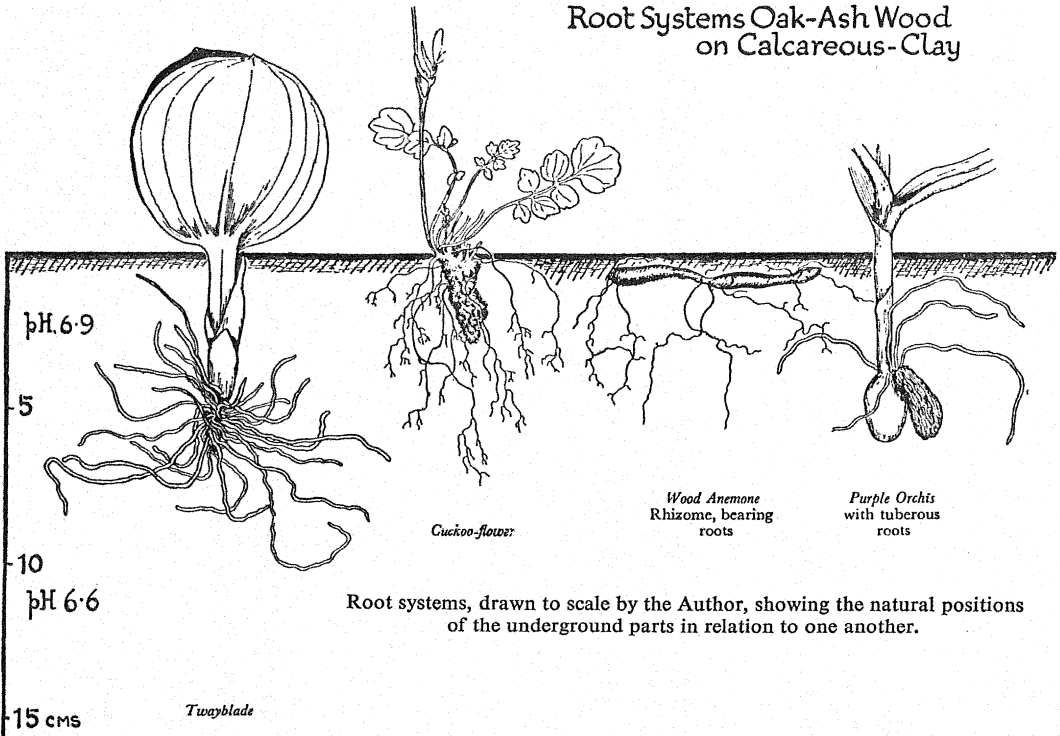


seen that those which grow deep down are commonly thick, robust structures, whilst those which grow near the surface are usually much more slender. The thin and superficial rhizomes of the May Lily or the Wood Sorrel contrast very strikingly with the robust and deep-seated rhizomes of the Solomon's Seal or Bracken.

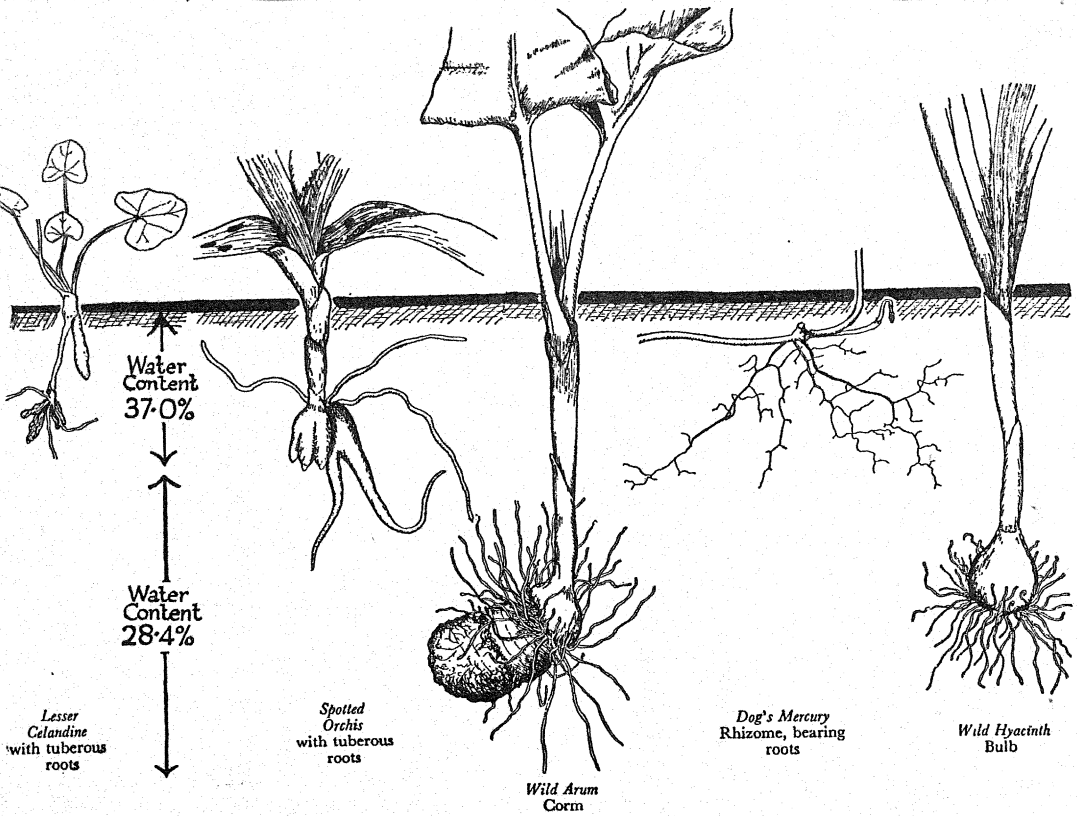
Not only have each of these underground stems and buds a characteristic depth for a particular kind of soil, but if the seeds of these plants are permitted to germinate on or near the surface, as they would under natural conditions, in a few years' time we shall find that the bulbs or rhizomes that the young plants have developed have come to occupy their appropriate horizon in the soil.

When we dig up a Crocus plant late in the spring after the flower has withered, we find a shrivelled corm, from which most of the stored food material has gone, bearing at its top the leafy shoot that has just flowered. The base of this leafy shoot is swollen, and already shows unmistakable signs of becoming a new corm, which enlarges as stores of food are passed into it

Root Systems Oak-Ash Wood on Calcareous-Clay

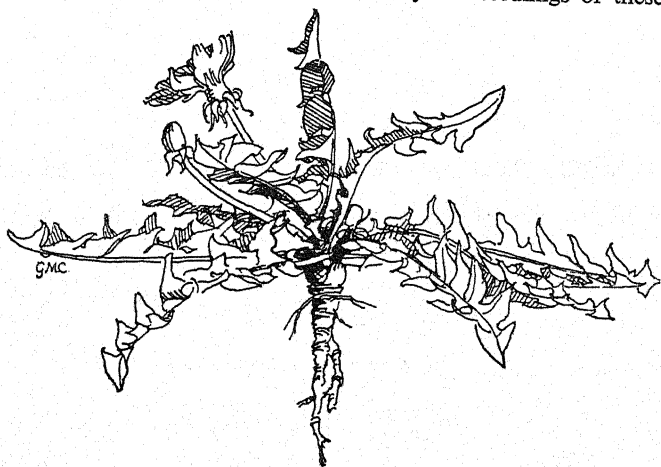


Root systems, drawn to scale by the Author, showing the natural positions of the underground parts in relation to one another.



from the leaves it bears. Underneath the old corm is a scar, or even the remains of the corm of the season previous. It is evident, then, that the corm of one year grows on the top of that of the previous year, and, as this is repeated annually, it is reasonable to expect that after a few years the new corms would appear above the ground.

That this condition is not actually found shows that there is some means by which the new corms come to occupy the same level as their predecessors. From the base of the corm there grow out in spring a number of roots, and some of these are much longer and stouter than the others. These stout roots have the peculiar characteristic of being able to change their shape, becoming shorter and at the same time stouter. The contraction in length draws down the new corm to the level of the old one, so that the upward growth is periodically corrected by the downward pull. The increased girth which accompanies the contraction is responsible for these roots retaining their anchorage in the soil, and that is why the corm is pulled down and not the roots up. It is the annual production of such contractile roots by Crocuses or Scillas that draws down the corm or bulb, which is first formed by the seedlings of these



plants close to the surface, so that it comes to occupy the level at which the adult corms and bulbs are found.

Plants with horizontal underground stems maintain their correct level by the upward or downward growth of the young apex. If we give a top dressing of soil to a bed of Lilies-of-the-Valley, we shall find that the newly formed shoots grow slightly upwards, whilst if soil be removed from the surface a downward growth is brought about. Since, as the depth from the surface increases, there is an increase of moisture but a decrease of air, it is probably the changes in these conditions which stimulate the upward or downward trend of the growing region.

If we look at a Dandelion plant or a Dock or any other perennial rosette plant, it is evident that the old leaves are those nearest the soil, and that the younger, more recently formed leaves are produced above them; so after a few years of growth we might expect to find the rosette of leaves well above the ground level. Actually here, too, there is a contraction of the root, which maintains the position of the rosette close to the surface, and it is to this contraction that the horizontal wrinkling of the roots is due.

CHAPTER VII

THE SPRING EMERGENCE

*'For he's bewitched forever who has seen,
Not with his eyes but with his vision, Spring
Flow down the woods and stipple leaves with sun.'*

V. SACKVILLE-WEST. THE LAND

FOR THE TRUE gardener each season has its own peculiar charm, and though May and June with their wealth of blossom represent perhaps the peak of realisation, yet the anticipations and surprises of springtime stand out as prominently, in part, because we have leisure to enjoy each in turn before we are distracted elsewhere.

The gradual emergence of the first shoots of the Snowdrops and Daffodils, the Hellebores and Winter Aconites, have an appeal that is scarcely surpassed by the flowers themselves. Actually this emergence is a feat in itself well deserving our consideration. The mere force exerted is comparable to that required to drive the growing tip of the root through the tightly packed soil, and is derived from the capacity of the living cells, of which the shoot and the root are alike built up, to take in water with great vigour.

The plant body can be thought of as a peculiarly shaped building containing multitudes of rooms of various forms and sizes, the walls of which are mostly quite porous. Each room at first contains living material which forms a lining to the porous wall, and is connected, through the walls, with the living contents of the neighbouring rooms. The greater part of most of the rooms is occupied with a watery fluid containing various substances in solution, many of which either cannot diffuse through the lining layer of living material or only do so at a very slow rate.

We all know that if we place a lump of sugar in a cup of water the whole cup will quickly become sweetened, the dissolved sugar and the water have become evenly mixed throughout. Without

going into the molecular processes involved, it is clear that there is some considerable force which brings about the mixing. Now if a strong sugar solution be separated from water by some material that will not allow the sugar to pass through but is completely permeable to the water, the same forces will come into play. But, as the sugar cannot pass through, the movement will be that of the water—in the direction of the sugar solution. The living substance which lines the wall of each plant cell (that we have likened to a room) forms such a 'semi-permeable' membrane.

When the plant is supplied with water, there comes into play the tendency of the water to mix with the dissolved substances in each of the rooms (or cells), and as most of these substances either cannot pass out, or only do so with difficulty, whilst the water can pass in freely, it is practically one way traffic. This causes the walls of the room (the cell walls) to stretch outwards until the attraction of the dissolved substances for the water is just balanced by the resistance to any further stretching which the walls of the rooms offer.

The force of attraction is dependent on the kind of dissolved substances present and their concentrations. Measurements have shown that the force with which water is sucked in by the cells composing the roots of a Daisy may be over ten atmospheres—in other words, to squeeze out the water from the cells of the Daisy root would require a pressure equivalent to that of a water column about 340 feet high.

The attraction of the cell-contents for water is greater the greater the concentration of the dissolved substances, but naturally when water is absorbed the solution is diluted and the attraction for more water is diminished. Also, the intake of water very soon extends the wall so much that the attraction of the diluted sap is no longer sufficient to overcome the squeezing influence of the stretched wall.

It is evident that a greater suction must be exerted by the plant to keep itself supplied with water when the soil is relatively dry than when the soil is moist. The suction force is regulated by alterations in the concentrations of substances in the cell

sap, as, for example, by the conversion of insoluble starch into soluble sugars, and vice versa. With increasing drought the plant cells develop a high concentration of dissolved substances and a correspondingly great capacity for sucking in water. How great depends very largely on the kind of plant, which is one of the reasons why some plants can grow in deserts and others only in damp places.

When the soil is moist the suction is diminished, partly of course because the cell sap is diluted with the water taken in, but also because of physical and chemical changes in the cell-contents. Herein lies a source of danger when we water plants during a period of drought. For after we have watered, the sucking power of the plant's roots is reduced and, even if we have thoroughly soaked the soil, the increased water-supply may have evaporated before the plant has regained its power of exerting a high suction. So the latter state may be worse than the first. The gardener has embodied this experience in the saying that 'if you once begin to water you must go on.' The freshening effect of a heavy dew, or of artificially spraying the foliage at night, is chiefly a consequence of the check it gives to evaporation from the leaves and so enables the rate of absorption to catch up, as it were, with the rate of water loss. The effect on the internal economy is slight as compared with waterlogging the soil in contact with the roots, and hence the plant's capacity to take in water during the heat of the following day is not impaired.

We have just seen that, though the forces at the disposal of the plant are very great, the distance over which they act is small for each cell separately; though as the plant grows the total effect of all the cells added together is very considerable indeed. It is like an enormously powerful hydraulic jack which operates very slowly but very surely. Hence we can understand how it is that the roots of plants can push their way through stiff clay, or the leaves of Dandelions through a layer of six inches of tar-paving with which they have been covered. Thus the seedling that germinated in a fissure of rock will, as it grows, split the mass in twain.

But if the driving forces are more than adequate for their purpose (and some plants can develop forces far greater even than those just mentioned) there still remains the fact that the growing tips of plants, whether roots or shoots, have to withstand considerable pressures as they are relentlessly forced through the soil. It is in this connection that we shall observe the most striking modifications.

If we were to see the tip of a root under a hand lens, we should find that its form was stream-lined. The actual tip is tapering, and bears a cap of cells that are constantly breaking down and becoming slimy on the surface, but are as constantly being renewed from within. In this way the tip of the root is lubricated in its passage through the soil.

Stem tips which have to push their way through the soil have no such lubricating device, but the part of the shoot which receives the brunt of the pressure is modified in various ways.

If we examine the shoots of the Daffodil as they emerge through the soil, we shall notice that all the leaves are packed together with their flat faces in contact with one another, but that one of the leaf-tips is in advance of the others.

As the first leaf emerges through the soil crust, the tip is seen to be much paler than the rest of the blade and harder to the touch. It is in fact an armoured point, and if we were to cut it through and examine it beneath a microscope the walls of the cells would be seen to be greatly thickened and altogether stronger than those of the lower part of the leaf. As the other leaves appear in turn, each is seen to have a similarly armoured tip, and, as each reaches the surface, it begins to curve away from the others so that when all the leaves are above the soil they are no longer packed together but each can obtain its share of light and air.

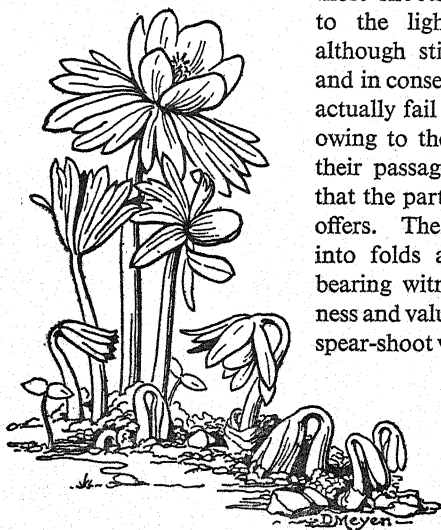
Let us now look at the emerging shoots of some Lilies-of-the-Valley which should be coming up about the same time. Each shoot as it pushes into the light and air will be seen to resemble a spear tapering to a hard tip, which is armoured in a manner similar to that of the Daffodil. Here, however, the leaves are rolled round one another, and it is the outermost leaf which

envelops the whole shoot that bears the armoured spear-tip. So long as the shoot remains in darkness, covered by the soil, it retains this spear-like form, but as soon as it reaches the light it begins to unfold. It might be thought that it was the pressure of the soil surrounding the shoot that prevented the leaves from unrolling till the shoot had reached the surface, but it can be shown by a simple experiment that the unrolling is in fact due to the stimulus of light.

If the Lily-of-the-Valley be planted under a heap of soil against which is laid a sheet of glass sloping slightly inwards, the shoot will grow up in contact with the glass face. If half of the glass face be covered whilst the other half is exposed, some of the shoots will be illuminated whilst still beneath the soil, whilst the others will serve as controls to show that growth in contact with the glass has not caused any abnormal development. It will be found that the shoots against the portion of the glass which is kept covered eventually reach the surface and expand in the normal manner on reaching the light. On the other hand,

those shoots which are exposed to the light begin to unfold although still beneath the soil, and in consequence will probably actually fail to attain the surface owing to the great resistance to their passage through the earth that the partially unfolded shoot offers. These shoots are thrown into folds and contorted, thus bearing witness to the effectiveness and value of the stream-lined spear-shoot with its armoured tip.

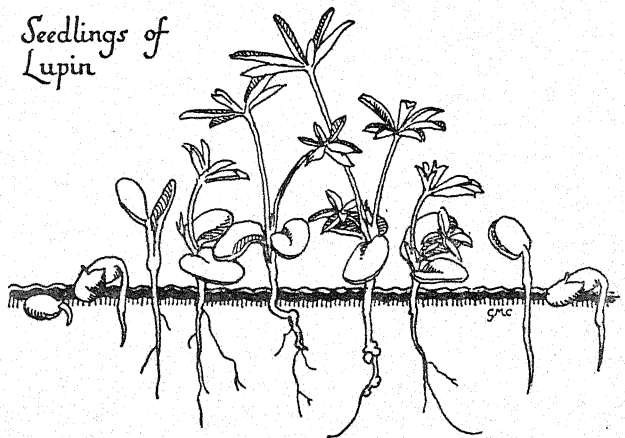
In most monocotyledonous plants spear-shoots of one type or another are found. The Solomon's Seal, the



terrestrial Orchids, and the wild Arum offer good examples, and amongst dicotyledonous plants spear-shoots are exemplified by the Globe Flower, the Hellebores, the Greater Willow-herb, and the Lesser Celandine.

In many dicotyledonous plants, however, the leaves are folded in the bud in quite a different manner, and here the leafy shoot is frequently drawn through the soil rather than pushed through. It is here the stem and not the leaves which exert the upward pressure on the soil. This is plainly seen in the flower shoots and leaves of the Winter Aconite, which both emerge through the surface crust as bent structures which straighten out when they reach the light. Here it is clearly not the tip of the shoot, but the bent part just behind the tip which receives the brunt of the pressure as it shoulders its way to the surface. Microscopic examination shows that in these, also, the cells of the region which receives the main pressure are strongly thickened. Experiments show that here too the stimulus which causes the shoot to straighten out when it reaches the surface is that of light. The leaves of many adult plants and many seedlings show a similarly bent structure as they push through the soil.

*Seedlings of
Lupin*



CHAPTER VIII

THE GARDEN COSMOPOLITAN

'With all thy getting get understanding.'

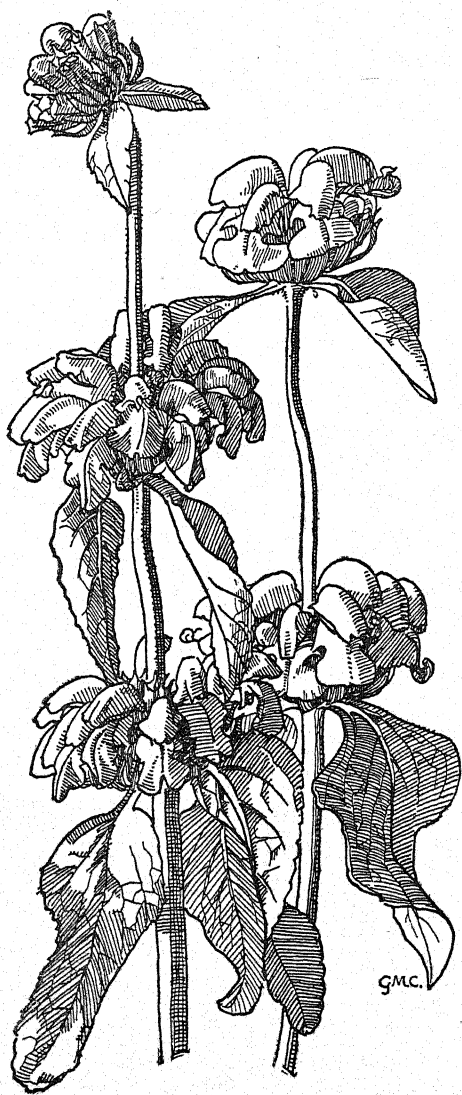
PROVERBS iv. 7

LET US WANDER around our garden and think of the many lands from which our plants have been culled. We shall probably be surprised at the diverse countries that are represented, even amongst the commoner flowers and shrubs, but still more amazing is the variety of situations from which they come—yet flourishing together under our care almost side by side: the Scarlet Anemones of Palestine; the Blue Himalayan Poppies; the Cone Flowers of the North American thickets; the dusky Monkshood from the pastures of the Alps; Rhododendrons from the forests of Western China and India; bulbous plants from the South African grass-veldt; rock plants from mountain ranges almost the world over.

Some of the earliest plants to be introduced into cultivation were aromatic herbs, and as the sun beats down upon our herb garden and makes the air redolent with their essential oils we think of the Mediterranean scrub, with its Lavender, Rosemary and Jerusalem Sage (*Phlomis*), Rue and Myrtle, Box and Strawberry-tree, made gay with the golden blossoms of the Spanish Broom (*Spartium junceum*) and the short-lived satiny flowers of the Rock Roses (*Cistus spp.*).

The woods of southern Europe have not only furnished us with shrubs such as the Bay Laurel, but from their herbaceous carpet come the Christmas Rose, the hardy Cyclamen, and the blue and yellow Anemones (*A. apennina* and *A. ranunculoides*), whilst at the woodland margins may be found the Leopard's Bane (*Doronicum plantagineum*) and the Sweet William.

The dry grassy banks of southern Europe have given us Cupid's Dart (*Catananche coerulea*) and the Burning Bush (*Dictamnus Fraxinella*), both of which were first brought to this



PHLOMIS, Fruticosa and Lychnitis

country at the end of the sixteenth century. From the waste ground of the Mediterranean come the Globe Thistle, and several Aristolochias, whilst the Sweet Pea is a native of Sicily.

The Virginian Stock, the name of which naturally suggests a native of eastern North America, is actually a native of the sandy shores of the Mediterranean.

The sight of our Oriental Poppies takes us further east to Asia Minor, whilst the perfume of the Lilac bushes and White Jasmine, the gay capitula of the Sweet Sultans and the stately inflorescences of the Crown Imperials, are fitting reminders of their Persian homes. Still farther east, the foothills of the Himalaya have yielded a rich harvest, and during recent years Kingdon Ward and other explorers have made the eastern Himalaya famous as the Land of the Blue Poppy (*Meconopsis betonicifolia*) and the home of that beautiful new genus of Lily, *Nomocharis*, which have their native homes at altitudes of between 11,000 and 13,000 ft. From the far-famed vales and mountains of Kashmir come a number of mountain species, conspicuous amongst which are several members of the Buttercup family. From here come the beautiful *Anemone tetrasepala*; the white variety of the Marsh Marigold (*Caltha palustris* v. *alba*); the early-flowering *Trollius acaulis*, and that Kashmirian gem *Adonis chrysocyathus*.

China has long been represented in our gardens by the Hollyhocks (*Althaea rosea*), which found their way to our gardens in 1573; the Balloon Flower (*Platycodon*), introduced in 1783; and the Wistaria (*W. chinensis*), which rapidly gained popularity after its introduction from the garden of a Canton merchant in 1816. It is difficult to realise that so familiar a feature of cottage gardens as the Bleeding Heart (*Dielytra*) was introduced from northern China less than a century ago.

Amongst other beautiful and familiar Chinese species may be mentioned the Tree Pæonies, *Thalictrum dipterocarpum*, the shrubby Plumbago-like *Ceratostigma Wilmottiana*, and *Corylopsis*.

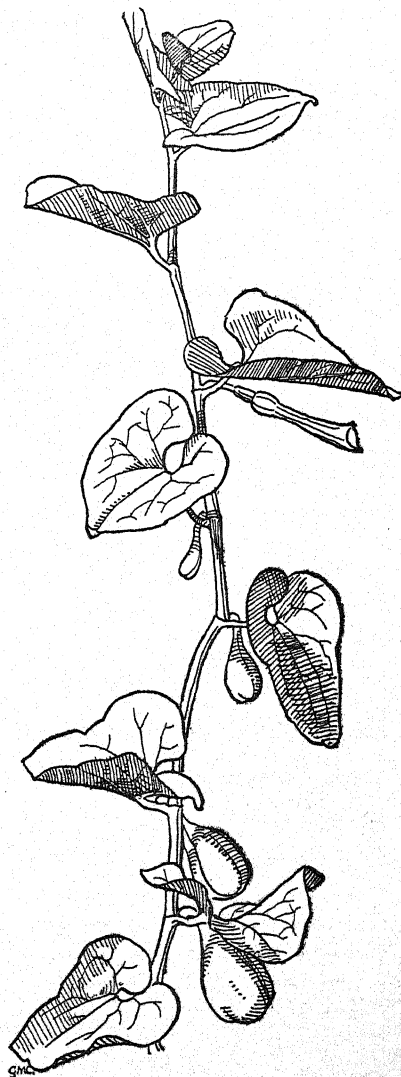
Japan is more famous among gardeners for its flame-coloured Quince (*Cydonia japonica*) and ornamental Cherries than for its

contributions to the herbaceous border, but the Plantain Lilies have, since the end of the eighteenth century, been prized alike for their foliage and their fragrant flowers, whilst the Japanese Anemones, from the damp mountain woods, and the Jew's Mallow (*Kerria japonica*) have long been a valued feature in the border and shrubbery respectively. The Japanese element in the shrubbery is usually a conspicuous one since to that land we owe the Deutzias, Diervillas, *Enkianthus campanulatus*, and *Lonicera japonica*.

The contributions of the New World, though often more recent introductions, are no less important than those from the Old.

As we gloat over the wealth of blossom in our autumn borders, with their Golden Rod, Black-eyed Susan, the Sunflower (*Helianthus rigidus*), and the Michaelmas Daisy (*Aster ericoides*), we can see these in imagination making gay the vast prairie regions of North America. There too we should find the Canadian Lily, the Blue-Eyed Grass (*Sisyrinchium*) and the Blazing Star (*Liatris*). Some

Aristolochia Sp.



of these are old garden friends which were brought from America in the reign of George II, about the middle of the eighteenth century, when the growing commercial intercourse with our Western possessions was soon to be followed by the annexation of Canada.

It was not till the middle of the nineteenth century that the rich harvest of American shrubs really began to be garnered, though the Tulip-tree (*Liriodendron tulipifera*) had already been introduced from there in 1663. This tree, of which such fine specimens are to be seen in some of the older gardens in southern England, not only carries the mind back to the earlier collectors of plants, but is itself in the nature of a 'living fossil.' Like the Maidenhair-tree, which comes from eastern Asia, the Tulip-tree at the present day only occurs as a wild plant over a very small part of the earth's surface, although abundant in the southern and eastern States. Both these trees before the last glacial epoch were, however, probably widespread in the northern hemisphere, but, when driven southwards by the increasing cold, found sanctuary, the one in the West and the other in the East. Other trees of ancient lineage which carry our minds back through space and time to the remote past are the Giant Sequoias of north-west America. Perhaps some of our garden herbs are of similarly ancient descent, though their remains are less readily preserved as fossils. Still, allowing for the probable imperfections of their record, it is unlikely that their direct lineage goes so far back as the Maidenhair-tree or the Wellingtonia, which both belong to groups that are represented in the record of the rocks before any signs of the flowering plants as we know them to-day are to be recognised.

From the woods of north-west America came that familiar evergreen shrub *Mahonia pinnata*, which in some gardens to-day is almost a weed; yet such was the enthusiasm with which it was first received that roots commanded a price of ten guineas each.

If the contributions from the northern States are more numerous, those from the States of the south-west are some of our most popular border annuals. From California the first half of the nineteenth century, between the years 1826 and 1835,

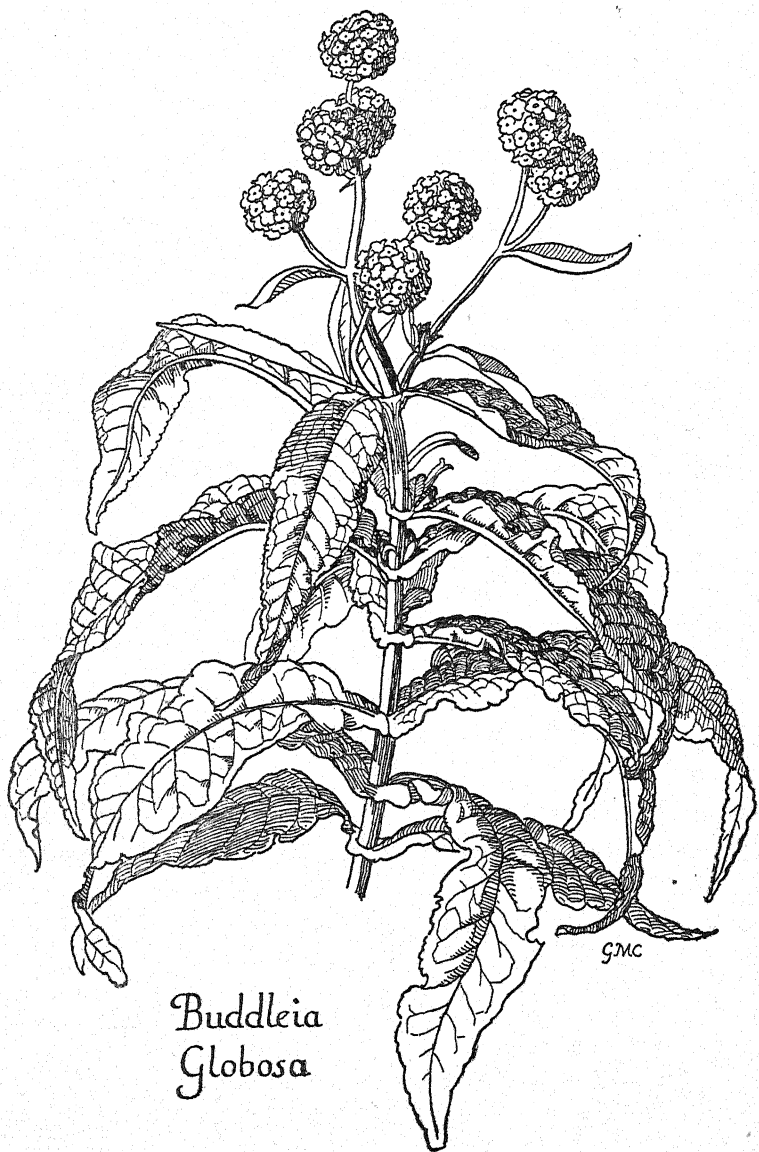
saw the successful introduction of Godetias, *Clarkia elegans*, *Eschscholzia californica*, *Nemophila insignis*, and *Bartonia aurea*. The delicately beautiful Californian Poppy (*Romneya Coulteri*), with its large satiny white flowers and mop of golden stamens, is one of the few perennial species introduced from California which is able to withstand our winters. Brought here nearly a century ago, it must still be regarded as half hardy, and, like the White Jasmine from Persia, which has been with us more than four hundred years, is still liable to be cut back by frost, and bears witness to the absence of acclimatisation in the true sense.

The early nineteenth century, that saw the introduction of annuals from California, was also the period of arrival in this country of *Phlox Drummondii* from Texas, an annual which attained a great popularity during the 'bedding period' of Victorian gardening.

From Mexico came the misnamed African Marigold in 1596, Zinnias some two hundred years later, whilst in the early years of the nineteenth century the same region furnished the Dahlias and the Scarlet Lobelia (*Lobelia fulgens*), to be followed in 1836 by Cosmos.

From the southern hemisphere come the garden Nasturtiums (*Tropaeolum majus*), the Canary Creeper (*T. canariensis-Aduncum*), and the Heliotrope; all natives of Peru. Even the Brazilian forests, though chiefly providing us with greenhouse flowers, have furnished an almost hardy climber in the Blue Passion Flower, whilst the same region has given us the hybrid bedding Verbenas and the scented Tobacco (*Nicotiana alata*). From the Argentine come our bedding Petunias, whilst Chile has furnished us with the Pincushion-tree (*Buddleia globosa*), the Herb Lilies (Alstroemeria), and two much-prized annuals, namely Salpiglossis and Schizanthus. From the island of Chiloe, off southern Chile, came that most beautiful of flowering shrubs, *Berberis Darwinii*, in 1849.

Few indeed are the gardens where we are not reminded of the early days of the Cape of Good Hope. Long before the British occupation of this area during the Napoleonic wars, the Dutch had been sending South African plants to Europe.



Buddleia
Globosa

Gladioli were first grown in England in 1596, whilst the end of the seventeenth century and the beginning of the eighteenth witnessed the successful introduction of *Agapanthus umbellatus*, the Red-hot Poker, and our bedding Pelargoniums, often, though incorrectly, called 'Geraniums.' From there, too, came later the Ixias, and a number of other bulbous plants, as well as species of Oxalis, in which the Cape flora is very rich. It is surprising to find that Nemesia, Ursinia, Dimorphotheca, and other annuals of deservedly great but comparatively recent popularity, were actually introduced into England from South Africa more than a hundred and fifty years ago.

The flora of New Zealand, very rich in endemics—that is, in species not found as native plants elsewhere—naturally attracted the attention of collectors soon after its colonisation, and amongst the most familiar of these peculiarly New Zealand flowers in our gardens are the shrubby Veronicas and the Daisy Bushes (*Olearia*), both of which, as native shrubs, are characteristic features of the sub-alpine scrub. The vegetation of marshy ground is represented by the New Zealand Flax, that grows so successfully in the West of England, whilst our rock gardens often contain representatives of two endemic genera, namely the vegetable Sheep (*Raoulia*) and those curious members of the Rose family, *Acaena*, both of which genera are characteristic of rocky ground.

The scarlet-flowered Parrots-Beak (*Clianthus puniceus*) is a rare plant of New Zealand which was cultivated by the Maoris and when first introduced into England in 1831 was sold for five pounds a plant. Its half-hardy character restricts its cultivation in the open to the warmer parts of the S.W. On a light soil *Leptospermum Chapmani*, a heath shrub from this region, will survive our winters and in July its small leaves are well-nigh smothered in the profusion of its rosy blossoms. That magnificent Forget-me-not (*Myosotidium hortensium*) is another species which is rapidly diminishing in its native home where it is confined to Chatham Island: though introduced some eighty years ago it is, like so many New Zealand plants, difficult to grow in England.

We have only selected a few examples of the more familiar plants from a number of different areas on the world's surface to illustrate the diversity of climes and habitats that are represented even in a garden that makes no pretence of growing any but the most ordinary kinds. There is romance in the thought of how the earth's surface has been ransacked to enrich our flower borders, in the travel and the hardship that have been endured to add one species to our garden flora, and not least in the thought of the unremitting labours by which so many have been successfully maintained in situations and under climatic conditions often very different from those of their native home. Also let us remember the vast multitude of species that have been tried and found wanting, for, though many are collected, few are chosen to survive.

CHAPTER IX

VEGETATIVE PROPAGATION

'If men could be propagated vegetatively the multiplication of genius would be simple, but the world would be an odd place to live in.'

ONE of the chief tasks of the garden lover is the maintenance of his stocks of plants, either by seed or by vegetative propagation.

If we wish to increase the number of plants of a particular kind, we employ vegetative means of propagation. We multiply our Pansies by 'cuttings,' our Michaelmas Daisies by 'division.' In the latter we divide the parent plant into a number of separate portions, each of which already bears roots, so that, as soon as contact with the soil is established by the formation of new root hairs, these separate portions can continue their growth with but little check. The newly rooted plants are in reality but severed parts of one individual, and this carries with it the advantage, from the gardener's point of view, that, as such, they all share the same characteristics—an important matter when we desire to plant a bed in which all the flowers shall be of the same shade. Being parts of one individual, we can be further assured that, if the conditions for their growth are uniform, all will be of approximately the same height and vigour, and develop with the same habit.

It is a familiar experience that amongst individuals of a single horticultural strain, raised from seed, which has been selected for, say, colour, there are liable to be differences, in vigour and form, in leaf size, and in height, of the adult plants. But by multiplying from a single individual, by means of division or by cuttings, we can usually avoid these differences entirely.

These methods are almost essential when we require a number of plants of a hybrid strain, since hybrids do not normally come true from seed. So, if we wish to avoid the necessity of repeated hybridisation, we must multiply our stock by cuttings. Many choice colours amongst hybrid Lupins cannot be raised from

seed, and our only means of increasing the number of plants is by striking green cuttings in the spring from the axillary shoots.

Cuttings usually consist of a small portion of a shoot cut off just below a node. So-called 'hardwood' cuttings are usually taken from the growth of the previous season, as contrasted with 'softwood' cuttings taken from the newly formed shoots. The latter are naturally more susceptible to dry conditions, and are commonly raised, in a frame or hothouse, in an atmosphere kept moist until the cuttings have formed roots which will maintain the necessary water-supply.

'Hardwood' cuttings can tolerate desiccation to a much greater degree, and so can often be rooted successfully in the open. The longer the period they need to become rooted—and this depends in considerable measure on the kind of plant—the more care must generally be taken to protect the cuttings.

If the cutting be taken with a 'heel'—that is, a lateral shoot is torn off with a small part of the parent stem attached—then the cutting often roots more readily than if cut off below the node. But taking cuttings with a heel is more damaging to the parent plant, and can only be adopted when small numbers of cuttings are required.

The number of different kinds of plants that can be increased by cuttings is far larger than many gardeners suppose. The essential conditions are: a maintenance of adequate moisture, so that the cuttings do not permanently wilt, and a good soil aeration. Except when the cutting is first planted good soil aeration is most important, since new roots will only develop from the cut end if the soil is well supplied with air. For this reason quartz sand is the best medium for rooting cuttings in cool conditions, and coco-nut fibre when rooting cuttings in heat. If cuttings be placed in a pot, some in contact with the sides and others towards the centre, the former will usually be found to root much more readily than the latter. This is largely due to the better aeration of the soil where it is in contact with the porous side of the pot.

In the stem and root of many plants there are certain regions

where the cells are still juvenile and undifferentiated and retain their power of growth and division. These regions, known as cambiums, are responsible for the increased girth of trees and for the continued production of cork at the surface, by which the trunk retains a protective covering despite its growth in thickness. It is from these actively dividing cells that the new growths of the cutting commonly develop. When a cutting is pushed into the sand, the active cells grow and form a healing tissue, or 'callus,' over the cut end, and from this new roots are formed. But the development of this callus appears to be stimulated by conditions less favourable for aeration than those which encourage new root formation. Perhaps it is for this reason that abundant watering is often found desirable at first, thus waterlogging the soil and ensuring poor aeration in the early stages, as well as preventing wilting.

The differences in the ease with which different kinds of plants root are very marked and characteristic. Though it is quite easy to strike cuttings of Roses, yet it is extremely difficult to do so with Pears and Apples, despite the fact that they belong to the same family. As regards trees and shrubs, it may be said that in general it is much more difficult to root cuttings of those which possess a large pith than of those in which the pith is small. If the pith is large, it is best to take cuttings from the small axillary shoots. But, though the ease with which success is achieved is to some extent related to the structure of the plant, the difficulties are often more abstruse.

The facility with which Willow cuttings strike is probably largely, if not entirely, due to the presence of rudimentary roots in the stem, already developed within the tissues of the parent axis, and merely awaiting the appropriate stimulus for their development. Tulip bulbs, which are in reality natural cuttings since they represent detached buds, likewise possess dormant roots buried in the tissue at the base of the bulb.

But many plants which are easy to strike have no such dormant roots. A plant of which one part is difficult to strike may be comparatively easy to multiply from another. *Acanthus* and *Anchusa* are, for instance, both readily raised from cuttings



Acanthus

of the root, but it would probably be difficult to obtain success with either their stems or leaves. Root cuttings are also the normal method of propagation for Sea Kale and Horseradish.

Some *Rhododendrons* can be raised with comparative ease from shoot cuttings, but a number are very difficult to strike, and resort is had to grafting upon the stock of an easily rooting species such as *Rhododendron ponticum*. With some of the species which are most difficult to induce to form roots upon cuttings of their shoots, successful results have been obtained by the ingenious method of grafting a root of *R. ponticum* into the base of the cutting just below a bud. Since in a *Rhododendron* adventitious shoots do not develop from the roots as they do in some plants, the result is similar to that of a plant on its own root system, and as the shoot develops the root grows with it. Subsequently the shoot may develop roots of its own, but this has only been rendered possible because the grafted roots have functioned during the prolonged period that elapses before the cutting roots itself.

New plants are easily raised from cuttings of the leaves of *Begonias* and *Gloxinias*, and, though this method of propagation seems very artificial, it is actually the normal method of vegetative multiplication in some plants, as, for example, in that curious greenhouse succulent *Bryophyllum* or the Candle Plant, *Kleinia*. In the former succulent, which is a tropical relative of the Stonecrops, shoots arise from the notches at the margin of the leaf, and each can develop into an independent plant. The herbaceous border furnishes a similar example in that peculiar ally of the Saxifrages, *Tolmeia Menziesii*, from western North America. The new individuals in this plant arise from the upper part of the leaf-stalk.

It has already been mentioned that Apples are difficult to strike as cuttings, but some can be rooted comparatively readily by the method we adopt with Carnations—namely, layering—though it is usually two years at least before the rooting is effectively accomplished. The work at the East Malling Research Station has shown that fruit-trees raised in this way on

their own roots are in the early years of their growth much slower than when grafted on to suitable stocks.

In the process of grafting, the base of a shoot, known as the 'scion,' is shaped and inserted into a previously prepared incision in the stem or branch of a rooted plant, known as the 'stock.' Good contact between the soft outer tissues of each is essential. The two are bound tightly together in such a way that the close contact is maintained, and the graft is often covered with wax to ensure that the junction does not become dry before union is established.

'Budding' involves the same essential process except that the scion consists merely of an axillary bud together with a small portion of the outer tissues of the stem on which it was borne. A diversity of methods as regards the type of incision in the stock, and consequently the form to which the base of the scion is shaped, is employed, but the essential principles remain the same. The valuable investigations of Dr. Hatton and his colleagues have shown the great importance of the nature of the root stock upon which the scion is budded or grafted, and the production of vegetatively multiplied stocks at East Malling has contributed in no small degree towards uniformity of stocks and so to the standardisation of commercial fruit-trees.

Grafting or budding has all the advantages of vegetative multiplication in that it ensures uniformity of the individuals obtained in this way. A hybrid Apple which will not breed true, or which may even be completely sterile, cannot be raised from seed, but may nevertheless be increased at will by these vegetative means of propagation. Furthermore, even if it were possible to keep the variety true to type when raised from seed, a period of probably seven to fifteen years would elapse before we should obtain any fruit from the young tree. By budding or grafting on suitable stocks we can obtain a fruiting tree in perhaps five years, a saving of time which is of no small importance to the grower and raiser alike.

But though multiplication by grafting or budding gives us uniformity as regards the variety of the fruit, the kind of stock we select upon which to graft or bud will profoundly influence

the growth of the tree. A variety of Apple grafted or budded on to one type of stock will make more than twice the growth that the same variety makes when a so-called dwarfing variety of stock is employed. Different stocks vary appreciably in their capacity for root development, which is perhaps also affected by the kind of scions that we graft upon them. In general, the 'dwarfing stocks' are associated with earlier and heavier cropping, as, for example, when the stock known as East Malling No. IV is used. On the other hand, stocks which tend to promote vigorous growth, such as Malling No. XII, generally produce trees that come into bearing later and do not at first crop so heavily. One would naturally expect early production of flowers and fruit to be associated with a check in vegetative growth, so that the more vigorous types of stock are naturally employed for standards and half-standards, where we desire a larger tree, and do not mind the consequent delay in attaining full cropping.

The effect of a particular stock may differ according to the scion that is grafted or budded upon it, which fact emphasises the mutual influences at work, but the relative effect of a dwarfing or vigorous stock on a particular variety appears to be the same on quite dissimilar types of soil. The type of stock has also been found to influence the size, the colour, and even the quality of the fruit produced by the scion, so that, whilst this type of vegetative propagation produces uniformity as regards the variety, it is a uniformity that is subject to considerable modification. However, the investigations at East Malling and Long Ashton have shown that this modification is in great measure capable of standardisation and control.

The general principles regarding the effect of stocks on scions which have been established for Apples appear to hold true for Pears and Plums also, and it is not improbable that they are broadly applicable to budding and grafting generally. Most of us have not the room in our gardens for a sufficient number of fruit-trees to observe these differences for ourselves, but the limitations of space are far less marked in respect to Roses, which in many gardens are often budded in considerable

numbers. By raising Rose seedlings as stocks from the various species we happen to be growing, we can easily test for ourselves this interesting physiological interplay between the constituent parts of the dual organism that we are about to create artificially.

The experience of generations of expert craftsmen has shown that species which can be successfully combined together by means of grafting or budding must be fairly closely related botanically. The modern system of botanical classification aims at an expression of the affinity between species; and the fact that the facility with which one plant can be grafted on another is usually greater the closer their proximity in our system of classification shows how well this system expresses the natural relations between plants. Varieties of the same species, or closely allied species, can usually be grafted on one another with success, whereas the grafting of a species of one genus on to a species of another generally presents greater difficulty, and the grafting of a scion of one family on to a stock of a member of another family is usually impossible.

The permanent union of scion and stock involves the harmonious growth of the tissues of both. Not only must there be intimate junction without incompatibility in respect of the chemical and physiological processes of the partners, but, unless there is to be subsequent rupture, the two must be comparably constructed and have similar rates of growth. In other words, neither their anatomy nor their physiology must be too dissimilar. The surprise is not, therefore, that the grafting of one species on another should so often be unsuccessful, but that permanent union between different kinds of plants should ever be possible. Mere superficial resemblance is not enough, as the earlier craftsmen found who were surprised to discover that it was not possible to graft the maple-like Plane-tree on to real Maples. Nevertheless, the most astounding temporary unions have been recorded, as, for example, the Rose grafted on to an Orange-tree which Evelyn observed in Holland. But even temporary unions have their uses, since the stock supplies a root system for a scion that is slow to develop roots of its own.

A Clematis upon its own root system is generally found to be

more satisfactory than when grafted. Many beautiful garden varieties—as, for instance, the familiar *C. Jackmani*—are hybrids, and commonly sterile. These can be multiplied by internode cuttings, which root ~~more~~ more readily than when the cutting is taken at the node in the usual manner. But a plant which will flower is more quickly and more certainly obtained by grafting the variety on to a seedling of the wild Old-man's-beard (*C. vitalba*) or the cultivated *Clematis viticella*. Moreover, if the grafted individual be planted with the region of union below the surface of the soil, in the space of a few years the grafted variety will have developed its own root system. Thus by the temporary utilisation of a stock we are able to tide over the long period of delay before an adequate root system is developed by the variety we wish to propagate, and we ultimately obtain the desired condition of the plant upon its own roots.

An interesting aspect of vegetative multiplication is that, in certain plants at least, cuttings, whether of leaves or stems or roots, appear to partake to some extent in the degree of maturity of the region of the plant from which they are taken. Plants raised by cuttings from adult flowering specimens of *Begonia* or *Gardenia*, for example, have been observed to flower earlier than those from cuttings of immature individuals. In species of Bear's Breech (*Acanthus*) the seedlings possess a different type of leaf from those of the adult, and intermediate foliage types are formed by the young plants as they grow older until they pass into the adult condition. If root cuttings be taken from different parts of the same root system, it has been noted that those plants raised from segments of the younger portions of the root take a longer period before they develop the adult type of foliage than those plants raised from the older portions of the root.

Although the same final result is usually obtained whatever part of the plant we utilise for vegetative propagation, there are some very striking exceptions. Cuttings of coniferous trees, taken from the main stem on the one hand and from lateral branches on the other, are known to yield trees that are permanently different in habit. Another instance is afforded by the

Bouvardia known as Bridesmaid, a variety with double pink flowers. Bouvardias can be raised from either shoot cuttings or root cuttings. If we strike shoot cuttings of Bridesmaid, the resulting plants produce pink flowers, as we naturally expect, but if we strike root cuttings, these produce flowers that are not pink but deep red. Shoots that arise from stem cuttings develop from superficial tissue, but shoots developed from the root cuttings arise from deeper seated tissue, as is usual in branches from the root. We may, therefore, justifiably conclude that the inner tissues of this plant are different from the outer tissues, but this does not of course explain the mystery as to how this distinction within the same plant has come about. Other similar instances are afforded by some of the 'fancy' Pelargoniums. The variety Mrs. Gordon, for example, when multiplied by shoot cuttings in the normal way, produces plants with the white flowers flushed with pink typical of the variety, but root cuttings yield plants bearing flowers which are a rich red.

Such instances are comparable to those curious products of grafting known for more than a hundred years, which are termed 'graft hybrids.' The classical example is the *Cytisus Adami* of our gardens, which was first produced near Paris by a nurseryman named Adam. For the purpose of obtaining standards of the purple Broom (*Cytisus purpureus*) it was the custom to graft that species on to a stock of the common yellow-flowered Laburnum. In this particular instance the scion subsequently died back, but a shoot arose from the region of junction that was intermediate in external appearance between the two species involved. There are a number of old trees in English gardens which are direct descendants, by vegetative propagation, of this remarkable shoot. These trees look rather like a small Laburnum, but the flowers are purplish-brown in colour and usually fail to set seed. When fertile seeds are formed, they produce quite normal Laburnums with the usual yellow flowers. A common feature of these trees is that they produce occasional shoots that are typical of the Laburnum and bear clear yellow flowers, and others, looking rather like 'witches' brooms,' that

are in every way like *Cytisus purpureus* and bear purple flowers.

It now seems almost certain that these so-called graft hybrids are not hybrids in the ordinary sense, but represent an association of the tissues of the two plants in which one contributes a skin of, it may be, one or several layers, and the other the tissues forming the core. Several graft hybrids are known in which the contributing plants are the Hawthorn and the Medlar. True hybrids are also known between these genera, and they differ in appearance from the graft hybrids.

Numerous graft hybrids have been produced, in which the plants involved are species of *Solanum*, by grafting the one plant upon the other, and after junction has been established the scion is pruned off. From the cut surface new shoots arise, and those developed from the line of junction often exhibit various types of association of the tissues of the two contributing species. When the tissue of one completely envelops the tissue of the other a graft hybrid results, but, since the reproductive cells of a plant are formed from a single layer and not from several, the seeds which such plants produce give rise to plants that are not intermediate in character. The familiar green and white Zonal Pelargonium with a white edge and a green centre, or vice versa, are probably plants of a similar character, as also the *Bouvardia* already referred to.

It is not suggested, however, that all these plants arose as a consequence of grafting, so it is useful to employ the term *chimaera*, which we can apply to any plant in which there is evidence of association together, in the one organism, of two or more tissues, each with its own hereditary characteristics and potentialities. In all kinds of *chimaeras* there is a marked tendency for shoots to be formed consisting of one component only. The comparatively stable association in which the tissue of one component covers the other like a glove (*periclinial chimaera*) is not the only type. There are others where the component tissues are irregularly associated, and these are very liable, sooner or later, to exhibit separation.

The essential difference between the graft hybrid and the true

hybrid is that in the former the two types of living material are situated in distinct cells, so that normal cell division during growth may easily bring about their complete separation. In the true hybrid the two types of living substance are situated in the same cell, and are less liable to separation by normal cell division, though such separation usually takes place during the special type of cell division that precedes the formation of sexual cells. The sexual cells of the periclinal chimaera are, as a consequence, of one kind only, yielding the type of plant that happens to form the sub-epidermal layer from which the sex cells arise. The sexual cells of the hybrid are of two kinds, some being similar to those of the one original parent, others being similar to those of the second parental type.

Vegetative multiplication, from the gardener's point of view, whether by means of cuttings, budding, or grafting, is thus mainly important as a means of increasing the number of 'individuals' whilst maintaining their uniformity. But we can, if we choose, modify this uniformity, to a very limited extent, by implanting our cutting either as a graft or bud into the tissues of another type of plant.

By grafting a grape-vine on to the root stock of a wild species of grape we can retain the fruit qualities of the former combined with the immunity of the latter from attack by the dreaded phylloxera disease. By budding a hybrid Tea Rose on to the stock of *Rosa rugosa* we can provide it with a root system far superior to its own. By selection of root stocks for our Apples we can influence the vigour of the tree, the age at which it fruits, the colour and quality of the apples it produces. All these we can achieve, but such effects are similar to those we might produce by changes in soil or manurial treatment. The stock is, as it were, a living soil in which we implant our bud or graft, and success must clearly depend upon the suitability of the medium.

The components in our artificially created partnership must not present chemical antagonism. In some unrelated plants which cannot be grafted upon one another, the proteins of the cells precipitate when they mingle, and the failure may well be

due to this cause. Grafts between species belonging to different genera are sometimes successful at first and then the scion dies. Subsequent attempts at grafting on the same stock fail. If we think of the scion and the stock in such instances as bearing a similar relation to that between parasite and host, such results suggest analogy with the immunity that develops in animals after an infection. A successful graft is, however, a symbiosis or balanced condition where both partners are dependent upon one another for their persistence.

CHAPTER X

SEED PRODUCTION: FERTILITY AND INHERITANCE

'If all the offspring of a spotted Orchis were to survive, the grandchildren of a single plant would nearly clothe, with one uniform green carpet, the entire surface of the land throughout the globe.'

CHARLES DARWIN. FERTILISATION OF ORCHIDS

'Desire not a multitude of unprofitable children.'

ECCLESIASTICUS xvi. 1.

IF THE GARDENER uses vegetative methods of propagation to ensure uniformity, it is equally true that he often employs reproduction by seed as a means of attaining diversity. By the exercise of sufficient care we can, of course, be sure that the plants raised from seed will be almost as uniform as those obtained from cuttings. But if we want variation we can often obtain it by selecting our plants from a large number of seedlings; whereas however many cuttings we raise they will in all probability be just like the plants from which they were taken.

Fertile seeds are, however, the outcome of a whole sequence of processes, failure in any one of which will involve failure in seed production. The plant must first produce flowers, and the formation of these not only requires a certain amount of nourishment, but certain conditions with respect to temperature and light are also essential. If the temperature be too low, or if the period of illumination each day be too long, or too short, the plant may grow very vigorously but remain in a purely vegetative state.

The so-called 'long-day' and 'short-day' plants have already been referred to (Chapter III), but a certain minimum intensity of light is essential to flowering in every plant, though the needs in this respect are very diverse. Solomon's Seal or *Gaultheria procumbens* will flower freely in comparatively deep shade, whilst many plants like the perennial Sunflowers will only flower freely in full sunshine.

It is also important to realise that the flower buds of quite a number of plants are formed in the year before that in which they bloom. The bloom of the Daffodil that expands in spring was formed in May of the year before; the Cherry-blossom which decks our orchards in April was already being formed in the previous July; whilst the 'Lamb's-tail' on our Filberts that shed their clouds of pollen in the winds of February were being formed some six months earlier. The February flowers of the Snowdrop begin to be developed in June, and are complete in all their parts by August. The flowers of the Yellow Jasmine, the Crocus, and the Mezereum, which gladden our eyes in early spring, are already being formed in the previous June.

Such long intervals between flower formation and blooming are not, however, characteristic of all plants, as is shown by our Roses. These begin to develop their flower buds a little over a week after they start to expand their shoots in spring, and flower-bud formation is completed in about a fortnight, although the blooms do not expand till later in the same season. Many herbaceous plants also form their flowers but a short time before they actually expand.

It is, therefore, the conditions of growth at a period often long before the actual flowering season that determine whether blossom shall develop or not. Also, though external conditions, which we can in part control, largely influence flower production, there are other, internal, influences that cannot be ignored. The tendency of Apple-trees to bloom freely every other year is perhaps the most familiar example of the rhythm in flowering which, though modified by external conditions, is seldom entirely suppressed. A very dry summer will often have an effect, analogous to root pruning, in stimulating the formation of blossom by fruit-trees; and even the flowering of herbaceous plants may be affected in a similar way—probably as a consequence of its influence upon the balance between the food made by the plant on the one hand, and, on the other, the water and mineral salts absorbed from the soil.

In a dry season the absorption of mineral salts and especially nitrates is meagre, whilst, unless the drought be extreme, owing

Haselnüsse.

Nuces Ponticae, Prænestinae, Auellanae.



Gestalt und Geschlecht.

HAZEL: from the *Herbal* of Matthiolus, 1563.

to bright sunshine the plant is able to manufacture a superfluity of sugars. When the balance between the two is upset in this direction flower and fruit formation are stimulated, whereas a disturbance of the balance in the reverse sense such as may result from wet or shaded conditions tends to promote vegetative vigour and a paucity of fruit.

When fully developed a typical flower is really a short shoot bearing organs of reproduction, instead of leaves only, as is the condition in a vegetative shoot.

Usually, as in a Wallflower or a single Rose, we can distinguish a green outer covering, the 'calyx,' which serves to protect the flower when in the bud stage, and sometimes remains as a protection to the young fruit—as is very evident in a Catmint or a Salvia. The small leaves which make up the calyx remind us of the little scales which protect the leaf-buds in winter, and, like them, they are often firm in texture and sometimes hairy. The calyx of the Eschscholzia is like an old-fashioned nightcap, which the flower doffs as soon as the petals expand. Here, as in other members of the Poppy tribe, it is evident that this green covering has served its purpose when the flower opens.

Within the protective covering there are the petals, which, in contrast to the calyx, are often very delicate in texture and brightly coloured. We know, all too well, how short a time the petals often remain once the flower opens. Indeed the flowers of the Sun Roses (*Cistus spp.*) last but a few hours. Our *Halimium algarvense* that was a blaze of gold in the morning is strewn with a litter of petals by the afternoon, and we are amazed to find the miracle of renewal repeated day by day. Such evanescent beauty shows how transitory is the service which the petals perform. Like the advertisements in our newspapers and on our hoardings, they but serve an ephemeral purpose to tell whoever it may concern that there is nectar or pollen to be had for the fetching.

Within the petals there are several or many slender-stalked structures with swollen heads. These 'stamens,' of which there are only six in a Wallflower, but very many in a Rose or a Poppy, each produce pollen in their swollen head which is termed the



ESCHSCHOLZIA

'anther.' Each pollen grain may produce a structure capable of fertilising the female cell or egg, and, since each stamen produces a large number of pollen grains, the opportunities for fertilisation are considerable.

The centre of the flower is occupied by one or more structures, termed the ovary, which contains the immature seeds known as 'ovules.' Whether this ovary, which we may think of as the immature fruit, consists of a single structure, as in a Primrose, or of many, as in a Blackberry or an Anemone, it usually ends above in a stalk-like portion bearing a little sticky enlargement at its tip. This sticky portion is the 'stigma,' and if the ovary consists of a number of separate parts each part has its own stigma.

Let us assume that the conditions were favourable to the first phase of seed production—the formation of flower buds. After the flower has opened the stamens split so that the pollen is exposed and the stigmas on the young ovary become receptive. The pollen must now be transferred to these stigmas, there to germinate and grow.

This process of transference, which we term pollination, may be the result of the pollen being blown by wind, or, more commonly, it is transported by insects which visit the blossoms either because of the nectar in the flowers or because they feed on some of the pollen. But suppose the agency be wind, this may not blow from the needed direction at the appropriate time; or suppose the agency be insects, the weather may be too cold and wet, so that no bees or butterflies are flying about just when their services are required. If flower formation be the first, pollination is, then, a second critical phase in the sequence of events leading to seed production.

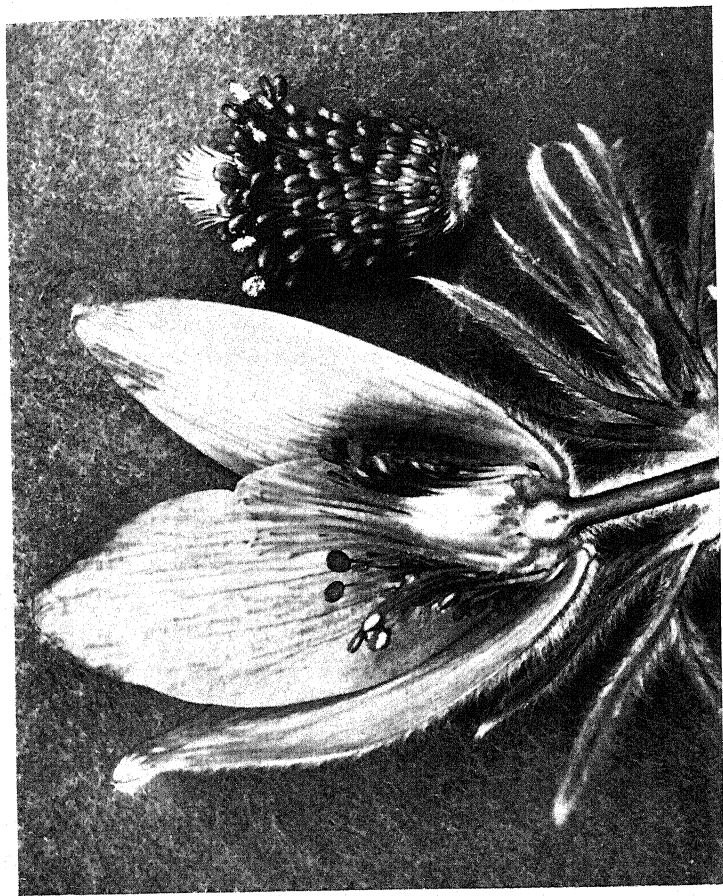
If the pollen has safely reached the sticky stigma, it must there germinate, nourished by a sugary secretion. The process of germination consists in the development of a thread-like tubular outgrowth from the pollen grain which grows down into the ovary, or immature fruit, and there this tube still grows on till it reaches the immature seed or ovule. From the tip of this pollen-tube there are liberated two bodies known as 'nuclei.' A tiny sac in the ovule contains eight such nuclei, but only three

of these need concern us here. Of these three, two join together before the arrival of the two nuclei from the pollen-tube; the other is the nucleus of the egg. When the two nuclei escape from the tip of the pollen-tube into the ovule, one fuses with the pair of nuclei which have already joined forces, and it is by the division of this triple fusion product that there is formed the nutritive tissue, known as 'endosperm,' destined to nourish the young embryo.

The second nucleus from the pollen-tube joins with the nucleus of the egg. It is this fusion which is the real act of fertilisation. There is good reason for believing that the nuclei are in large part associated with the transmission of the inherited characters, so that if the two fusing nuclei are qualitatively alike—that is, are the products of two similar individuals—the embryo which results from the process of fertilisation will grow into a plant that is a replica of both its parents. If, however, the two fusing nuclei are from different strains of the same species, the resulting embryo may develop into a plant that resembles one or other of its parents or it may differ from both. The two conditions are alike known to occur, but in either event, if a second generation of plants be raised by self-pollination—that is, by fertilisation of the ovules with pollen from the same plant—the resulting offspring, when they mature, will be found to comprise some individuals which resemble one of the original parents, some which resemble the other original parent, and still others which resemble the first generation.

This tendency for parental characters, temporarily combined, to separate out in subsequent generations (termed segregation of characters) is one of fundamental importance. But, since such separation is not always complete and only applies to characteristics of an alternative nature, it is possible by such crosses to bring together into one individual characters which were previously found only in distinct strains.

It is thus that the breeder has succeeded in combining the high-yielding qualities of cultivated strains of wheat with the immunity from disease exhibited by certain wild species whose yield of grain was low and of poor quality.



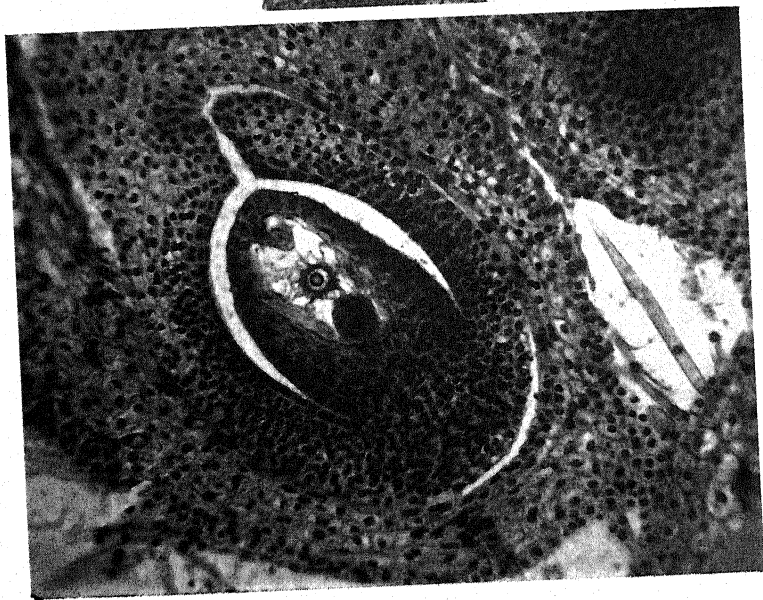
PASQUE FLOWER
(*Anemone pulsatilla*)
Vertical section showing the stamens surrounding a tuft of carpels. On the right: a group of stamens with protruding stigmatic tips of carpels. The lighter-coloured anthers of the uppermost stamens are shedding their pollen [x 2]

PLATE VI

CARPELS OF THE BLUE
ANEMONE (*A. apennina*)

Right: A single fertile
ovule is seen in the left-
hand carpel [x 47]

Below: The same ovule
much enlarged. In the
centre, the nucleus which
after fertilisation produces
a nutritive tissue, and the
egg cell near the tip [x 140]



In the early days of horticulture the grower depended mainly on chance crosses in the normal course of his avocations, and adopted a Micawber-like attitude—waiting for something to turn up. Since the stocks grown were large, and little care was taken to prevent crossing, new types were occasionally produced that were worthy of perpetuation. One of the most popular of flowering shrubs, *Berberis stenophylla*, arose in this way, as a chance hybrid, in a nursery near Sheffield, about 1860. Nowadays, the grower deliberately crosses desirable varieties with the definite object of obtaining a strain combining the virtues, and, if possible, eliminating the vices, of both. If it be the first-generation cross that is the desirable one, then recourse must be had to vegetate multiplication to avoid segregation. In later generations the desired combination may be present in a true breeding form, which can then be perpetuated from seed.

But let us turn once more to the time when the pollen from the stamens has reached the stigma.

It by no means follows as a matter of course that fertilisation will be the sequel to pollination. Pollen from a totally different kind of plant would be quite likely not to germinate at all. This fact does not surprise us. But the behaviour of pollen from individuals of the same species may vary widely in its efficacy according to the kind of plant involved, and whether or not the pollen is from a flower of the same individual.

There are some garden plants which are completely self-incompatible—that is to say, pollen from any flower of a particular individual is impotent to effect fertilisation of its own ovules although this same pollen will be quite efficacious if it reaches the stigmas in the flowers of another individual of the same species. Examples of such self-incompatibility are furnished by the Californian Poppy (*Eschscholzia*), Scarlet Lobelia (*Lobelia fulgens*), and *Verbascum Phoeniceum*. If we were to grow isolated plants of these species, no fertile seed would be set unless pollen were brought from another individual. Some garden plants produce strains that vary in respect to their fertility—as, for instance, the Snapdragon, the Mignonette, and

Tobacco, some of the strains of which are self-incompatible whilst others are self-fertile.

A large number of different kinds of plants are partially self-fertile, but produce good seed much more readily when cross-fertilised (i.e. fertilised by pollen from flowers of another plant) than when self-fertilised, and, as Darwin showed for Cabbages, the offspring resulting from cross-pollination may be appreciably more vigorous than those which are the outcome of self-pollination. Recent experiments employing modern technique have confirmed Darwin's conclusions; the mature Cabbages derived by cross-fertilisation being over 25 per cent heavier than those obtained by self-fertilisation. Similar results have been obtained with Onions and Runner Beans, in both of which the plants produced through self-pollination yielded less seed than when cross-pollinated, but there was no evidence that such seed as was produced was inferior in quality as a consequence of the inbreeding.

If we examine a large number of different flowers in our garden to see at what stage the pollen is shed and when the stigma becomes sticky and receptive, we shall soon discover that it is the exception for the stamens and stigmas to attain maturity at the same time. If we look at flowers of different ages on a Saxifrage, a Canterbury Bell, or a garden Geranium, we shall see that the pollen is shed some time before the stigmas are ready to receive pollen. Indeed in the Saxifrage this is so markedly the case that the pollen-bearing parts of the stamens have often all been shed before the two stigmas on their horn-like stalks are in a receptive condition. In a Magnolia the sequence is reversed, and we find the stigmas have completely withered away before the pollen in the same flower has been liberated.

Whether stamens or stigmas develop first it is evident that their differing times of maturity will tend to prevent self-pollination, although, if the plant is not actually self-incompatible, pollination between flowers of different ages on the same plant is not impossible. In the Walnut, although both female and male flowers are borne on the same tree, there is sometimes an appreciable interval in their respective periods of development,



and as all the flowers of the same sex on a particular tree mature at about the same time this is sometimes a cause of unfruitfulness in isolated Walnut-trees.

Where, as in the *Aucuba* and *Hippophae*, the flowers containing the stamens and those containing the potential fruits are borne on different plants, self-pollination is, of course, impossible; hence the necessity for ensuring that we have planted both 'male' and 'female' individuals in our garden if we are to enjoy the beauty of their fruits.

In not a few plants which depend on insect agency for the carriage of their pollen the actual flower structure tends to prevent self-pollination. In the familiar Pansy, for example, there is a little hinged flap below the stigmatic surface, and, although this does not prevent the stigma from receiving pollen which is already on the insect's tongue as this enters the flower to suck up nectar, the flap excludes pollen from the same flower, which may adhere to the tongue as it is withdrawn, since movement in this direction closes the flap over the stigma.

It is true that some plants, and these quite successful ones, such as that common weed the Shepherd's Purse, or the Sweet Pea, are normally self-pollinated, but the widespread occurrence and variety of the features which tend to prevent self-pollination suggest that, in general, cross-pollination, and, as a consequence, cross-fertilisation, is more beneficial.

Actually in some plants belonging to diverse families the failure of effective self-fertilisation is known to be due to the slow growth of the pollen-tubes, which do not reach the ovules. If, by a surgical operation, we shorten the distance that the pollen-tubes have to traverse to reach the ovules, we can, in some instances, bring about self-fertilisation. It is for a similar reason that we can make a cross between species of certain genera of Orchids when one is used as the female parent and the other as the male, but not when the rôles are reversed. In *Cattleya* for instance the distance between the stigmas and the ovules is relatively long, and the pollen-tubes of this genus are long in proportion, whilst in the genus *Sophronis* the distance is relatively short, and so, too, are the pollen-tubes. If we use

Cattleya as the female parent, the pollen-tubes of *Sophronitis* usually fail to reach the ovules—a difficulty that does not arise when the cross is made in the reverse direction by placing the pollen of *Cattleya* on the stigma of *Sophronitis*, since there is now a relatively short distance to be traversed by pollen-tubes that normally grow to a greater length. In Cabbages effective fertilisation can be obtained when self-pollinated, by applying the pollen to the stigma before the flower opens, thus allowing a longer period for the pollen-tube to grow.

From the gardener's point of view we can in fact regard the pollen grain as comparable to a seed, in that from it there grows a little plant, albeit of a very simple character. A suitable medium is essential for the growth of this tube-like plant. This medium is provided by a sugary secretion on the papillate surface of the stigma, and by the sugary contents of the soft-walled cells that form the core of the stalk, or 'style,' joining stigma to ovary. Sometimes there is an actual canal down this style, lined with sugar-secreting cells similar to those on the stigma. So is this small plant nourished as it grows out from the pollen grain down the style till it reaches the ovules in the ovary, converting the ovules into seeds, and causing changes in the ovary so that it becomes what we term the fruit.

It is, perhaps, the proteins associated with the sugars which are responsible for the difference in behaviour of the pollen on stigmas of different species, as these complex chemical compounds are known often to be peculiar to the species and even to a particular strain. But, whatever the actual substances involved, the great sensitiveness of the pollen-tube to the medium in which it grows is quite evident from those instances where perfectly good pollen fails to develop effectively on the stigmas of the same individual which produced it—the condition that we term self-incompatibility.

For the gardener, self-incompatibility attains great importance where, as in many fruit-trees, not only is the flower self-incompatible as regards its own pollen, but more or less completely so in respect to pollen from other trees of the same variety. This is to be expected, since in so many instances the

trees are in reality but separated parts of one individual. But sometimes even related varieties are self-incompatible in respect to one another. The familiar Cox's Orange Pippin is an Apple that is almost completely self-incompatible, and so, too, is the old Greengage Plum. The grower who planted an orchard with these varieties alone would pay dearly for his ignorance, and such isolation of varieties which are infertile when self-pollinated is no uncommon mistake in small gardens where only a few trees are grown.

Most Apples, particularly Cox's, Margil, and Gascoigne's Scarlet, can for practical purposes be regarded as completely self-incompatible. A few, such as Ribston Pippin and Cellini Pippin, may set a small proportion of fruit when self-pollinated. Cox's will set fruit when pollinated by most other varieties, though the proportion is low when the pollen-producing tree is itself a hybrid of Cox's Orange Pippin. Mixed plantations of several varieties are the practical solution of the problem, but, if there is only room for a few trees, varieties of closely related parentage should be avoided.

Many Pears are self-incompatible, and these include some of the most famous varieties, such as Doyenne du Comice, Beurre Hardy, Josephine de Malines, Thompson's, etc. On the other hand a few are markedly self-fertile, the best known of these being Bergamotte d'Esperon and Dr. Jules Guyot. The well-known Williams' Bon Chretien will set a certain proportion of fruit when self-pollinated, and Louise Bonne of Jersey is also to some extent self-fertile. Even the so-called self-fertile varieties produce much heavier crops, however, when cross-pollinated. Both Doyenne du Comice and Williams' Bon Chretien will set heavy crops when pollinated by Beurre Bedford, a variety which is itself appreciably self-fertile.

The sour Cherries are mostly self-fertile, hence we can get good crops from isolated trees of the Morello variety; but the sweet dessert Cherries are practically self-incompatible, the old Hertfordshire Black being one of the few exceptions. The sweet Cherries further constitute groups, all the varieties in a group being ineffective as pollinators of one another.

Amongst the Plums, some well-known varieties, such as the Victoria, Laxton's Gage, Golden Transparent, Denniston's Superb, and Czar, produce good crops of fruit when self-pollinated; others, such as the Greengage, Coe's Golden Drop, Jefferson, and Pond's Seedling, produce no fruit when self-pollinated. The popular River's Early Prolific is one of the plums that is partially self-fertile, but produces heavier crops when cross-pollinated. The Damsons exhibit similar differences. Most produce no fruit when self-pollinated, but an exception is King of the Damsons, which is completely self-fertile, whilst the Farleigh Damson is partially so.

It may be mentioned that effective pollination for fruit production does not necessarily involve the formation of fertile seeds, since in Apples, for example, pollination alone may be sufficient to cause development of the fruit although fertilisation is not effected. This phenomenon, known to botanists as parthenocarp, is found in an extreme condition in some tropical fruits, as, for instance, in the cultivated races of the Banana and the Pineapple. In neither of these 'fruits' do we find any seeds present. Though fertilisation is impossible, since ovules are not formed, yet pollination appears to furnish a stimulus to the development of the seedless fruits of *Citrus* and perhaps in other instances also.

Many cultivated varieties of fruit exhibit a partial or complete sterility, which may be shown by the small proportion of good pollen or fertile seeds which they form, or by their failure to produce either. This condition has in most plants arisen from the result of crossing, which has brought about an unbalanced condition in the sexual cells. Some varieties of Apples produce only a low proportion of good pollen, as, for instance, Ribston Pippin, Bramley's Seedling, and Blenheim Orange. Varieties which yield a high proportion of good pollen are therefore to be preferred as pollinators for other varieties. Amongst dessert Apples, Cox's Orange Pippin, Beauty of Bath, and Worcester Permain are a few of those which produce abundant good pollen, and examples among the culinary varieties are furnished by Lane's Prince Albert and Lord Derby.

By crossing together compatible strains, varieties, or even, it may be, species, we can endeavour to raise new kinds of garden plants which shall combine the characters of the two parental types. So many desirable plants have been obtained in this way that it is almost invidious to cite examples. In the shrubbery, the thought of hybrids at once suggests x *Viburnum Burkwoodii*, produced by crossing the evergreen *Viburnum utile* with the later blooming *Viburnum Carlesii*. The resulting shrub has both scent and flowering period intermediate between the two parents. x *Ribes Gordonianum* which is the progeny of the Red Flowering Currant (*Ribes sanguineum*) and the yellow Buffalo Currant (*R. aureum*), produces flowers which are red on the outside and yellow tinged with red within. Another early hybrid shrub is the Rhododendron x *R. praecox*, which was the product of a cross, made some seventy-five years ago, between the half-hardy evergreen *R. ciliatum* and the semi-deciduous *R. dahuricum*. It has the merit of blossoming in February, and yet is quite hardy. The beautiful ornamental Crab known as x *Pyrus Eleyi* was the result of hybridising the familiar Japanese *Pyrus spectabilis* with the unpronounceable *Pyrus Niederswetkyana*, from Siberia, yielding a tree remarkable alike for its red flowers, its plum-like fruits, and its purple foliage. The genus *Cistus*, which has been studied intensively both by Professor Gard in France and by Sir Oscar Warburg in this country, has been found especially prone to hybridisation in nature, and the beautiful cross between *Cistus ladaniferus* and *C. villosus*, known as x *C. purpureus*, has long been a valued feature of our gardens. Its large satiny pink flowers, with a brownish blotch at the base of each petal, are produced in great profusion. A well-grown bush, over four feet in height, with perhaps more than fifty flowers open at once, and renewed daily for some weeks, is as beautiful to behold as it is wonderful to contemplate. This and another hybrid, x *Cistus cyprius*, are not only two of the most beautiful members of this genus, but, with the exception of *C. laurifolius*, perhaps the most hardy and tolerant of our climate.

The half-hardy crimson-flowered *Escallonia punctata* gave origin, through crossing with the hardy white-flowered *E.*

Philippiana, to the graceful and, on sandy soils, quite hardy, x *E. Langleyensis*, with arching sprays of bright red blooms.

Other hybrids of the shrub garden that deserve mention are x *Ceanothus Gloire de Versailles*, x *Cytisus purpureus*, and x *Spiraea arguta*. Many more might be cited, but these suffice to show how much our shrub gardens owe to the hybridist.

When we turn to the herbaceous border and the rock garden we find that here, too, hybridisation has played an important part. We need only recall the hybrid Lupins, the hybrid Lilies and Daffodils, such plants as x *Dianthus Allwoodii* and x *Cheiranthus Helionii*, or, in the rock garden, x *Saxifraga Elizabethae*, to appreciate that this is an important means of acquiring fresh types, sometimes intermediate between their parents, sometimes presenting features that are novel, but not always, be it remembered, superior to the old and long-tried favourites. In the hothouse the profusion of hybrids amongst orchids includes crosses not only between different species and genera, but not uncommonly tri-generic crosses also in which the hybrid between members of different genera is itself hybridised with a species belonging to still a third genus.

But, whilst hybridisation is so important a means of production of new horticultural types, these may also arise in a pure strain as sudden and heritable differences from the parental stock. Novelties of this nature, once known as 'sports' and now termed 'mutations,' breed true to the new features from the outset. Why the change in the hereditary constitution takes place we do not as yet know, but the fact that the number of mutations can be increased by changing the external conditions—as, for instance, by subjecting the germ cells of the plant to X-rays—suggests that the environment provides the stimulus for their production.

Professor Bauer, who has bred Snapdragons on an extensive scale, found that from 1.3 per cent to as many as 7 per cent of the individuals exhibited mutation, whilst if subjected to X-rays the mutations became almost twelve times as frequent. The change of internal conditions which is brought about by hybridisation may also accelerate mutation, and as Professor Bauer's

Antirrhinums were hybrid strains we must not suppose that all plants would exhibit mutation at the same rate. Indeed the degree of mutation would appear to vary greatly in different genera and species.

That we do not see these mutations more frequently in our gardens is probably to be attributed to three causes: Firstly, the frequency of mutations being normally low, unless a large number of seedlings be raised the chance of their occurrence is small. Secondly, mutations which are conspicuously different from the parental type are very rare; more often the mutants are characterised by relatively insignificant distinctions that are readily overlooked except by the specialist. Thirdly, mutants are quite commonly less robust than the parental type, so that they often succumb to the competition of the seed-bed. If seedlings be pricked out, so that competition is minimised, we nevertheless, either consciously or unconsciously, generally select the more robust plants and omit to plant out the less healthy. It is the latter which often include the mutations, so that if we would seek novelties, every seedling, however apparently weakly, should be planted.

Amongst well-known horticultural varieties that have arisen by mutation may be mentioned the waved Spencer type of Sweet Pea, which arose from the variety Prima Donna, and the dwarf Cupid type that arose from Emily Henderson; the fern-leaved mutant of *Primula sinensis* and the dwarf variety of *Campanula persicifolia*, known to horticulture as *Campanula nitida*. Other examples which doubtless arose in this way are the Shirley Poppy, the Cactus Dahlia, and the numerous white varieties of normally coloured flowers. Amongst vegetables the familiar Cauliflower and the Kohl Rabi probably arose as mutants of the wild Cabbage.

The changes observed in these mutants appear to be associated with changes in the nuclear material with which inheritance is apparently connected. The changes due to hybridisation are probably an accompaniment of rearrangement and recombination of the nuclear material provided by the two parents. What is responsible for changes in the hereditary characters associated

with the cytoplasm we do not know. That we are far, as yet, from understanding fully the mechanism of heredity, is shown by the fact that the two generations of a Fern plant, though so different that they would be classed in separate groups of the vegetable kingdom were the life-history not known, both contain apparently identical nuclear material.

CHAPTER XI

SCENT AND COLOUR

*'I know
that if odour were visible as color is, I'd see
the summer garden aureoled in rainbow clouds.'*

ROBERT BRIDGES. THE TESTAMENT OF BEAUTY

FORM, COLOUR, AND SCENT—these are the chief qualities upon which we depend to make a garden of delight. Form, as in all artistic achievements, should rank first, but, curiously enough, though we pay due attention to the plan of our gardens, the actual form of the plants themselves does not receive the consideration it deserves. Particularly in the choice of varieties we must have regard, not merely to the height, but to the mode of growth. Flowering shrubs, for instance, are all too frequently pruned with sole regard to their flowering capacity, whilst shape, if it be considered, is often not that form which nature intended the shrub to assume.

Size, colour, and the period of flowering are the qualities most commonly taken into account when planting a herbaceous border or a shrubbery. But the mode of growth of the individual plants is equally important, and it will add not a little to the success of the whole if we also take thought for that much-neglected asset, scent. It may be the scent is that of the foliage, as in our hedges of Lavender, Cotton Lavender, Rosemary, and Old Man, which remind us of the herb gardens of former days. Perhaps it is the incense-like odour of *Cistus laurifolius* in the hot sun, the pleasing perfume of the expanding Pine buds, or the Caraway-scented foliage of *Thymus herba-baroni*. More frequently we think of scent in the garden associated with flowers. The fragrance of *Daphne mezereum* and *Viburnum fragrans*, of Violets and Wallflowers in spring; of Mock Orange and Lilac, Roses, Jasmine, Honeysuckle, and Sweet Peas in the summer; the honey-like odour of the Buddleia, to which the

butterflies flock in the autumn, or the perfumed beds of Mignonne and Stock, of Wallflower and Verbena. But there are many other scented plants that deserve to be much more widely planted. The violet-scented *Iris reticulata*, the rather Jasmine-like *Osmanthus Delavayi*, the curiously perfumed *Philadelphus purpureo-maculata*, the clove-scented *Ribes aureum*, the shrubby lilac-scented *Lonicera syringantha*, are but a few plants of comparatively easy culture which should be much more frequently grown.

The amount of scent emitted is partly determined by conditions of growth, but different strains of the same species vary widely in their potentialities of scent production. An observation of especial interest to gardeners is that the scent of fruits and flowers grown under red glass is markedly enhanced. The aroma of strawberries is alleged to be wonderfully improved by this means, whilst the almost scentless flowers of *Crassula* are stated to acquire a delicious fragrance. It is perhaps the greater heating effect of the long-wave red light as compared with ordinary daylight which is mainly responsible for these effects, rather than the light as such. If we grow aromatic plants in sheltered sunny situations on a dry soil, so that they enjoy a maximum of heat, their perfume is noticeably improved. This is partly due to the greater volatilisation of the ethereal oils rather than to an increase in their amount, but the yield of oil from such plants is actually higher when calculated on the basis of the dry weight.

One is often asked, Why is one flower scented and another not? The question places one on the horns of a dilemma, since to say merely, as I am tempted, 'I do not know,' may be as misleading as a so-called 'explanation' that is but the substitution of one ignorance for another.

The organic chemist will tell you that the scents of the flowers are caused by the presence of substances of varying chemical constitution but most commonly belonging to a group of compounds known as 'terpenes,' containing hydrogen atoms and carbon atoms, the latter being joined in a ring. But, even if we knew all that has been discovered respecting the complex

chemistry of these 'essential oils,' it is doubtful if it would help us much to understand why one plant is scented and another not. It seems not unlikely that these substances which stimulate our sense of smell are by-products of the plant's manufacturing processes. Nevertheless, if this be so, they are by-products which for many species would appear to be important assets either for the plant itself or for the perpetuation of the race. If we are not prepared to follow the organic chemist through the whole intricate and skilled performance as he juggles with the 'benzene rings,' we can at least realise the wide variety of figures he presents. Although the constituent elements be few—only carbon, hydrogen, and oxygen—their arrangements may offer astounding diversity, like a combination lock in which, though the letters are always the same, the number of possible arrangements is stupendous. Thus it is that most of the species of Eucalyptus have each their characteristic scent, and one species of Thyme emits the scent that has inspired poets whilst another closely related species smells of Caraway.

But if the chemist has helped us to understand how such diversity is possible, he, no less than we, is still amazed at such a diversity of products from plants whose fundamental processes are so essentially similar. Still more do we wonder why Honey-suckles, such as the Woodbine and *Lonicera syringantha*, produce so much essential oil that the air is redolent with their flowers, whereas the Fly Honeysuckle has flowers that are almost scentless; why *Viburnum Carlesii* appeals to our sense of smell and sight, whereas the Guelder Rose *Viburnum Opulus* only delights our eyes.

Let us, then, look at scent from another angle. If we walk round our garden and note which flowers are scented and which are not, we shall soon be struck by the fact that those which are markedly perfumed depend upon insect agents for the transfer of their pollen from one flower to another. Some, such as the Night-scented Stock, the Tobacco, the Butterfly Orchis, and the Honeysuckle, are either much more strongly scented after dusk or may even be quite scentless during the daytime. These flowers are all visited by moths that are night-flying insects.



Such observations suggest that the emission of scent may have been developed in relation to insect visitation, and this idea gains support from the pale colours of these flowers and their tubular corollas, which render them peculiarly fitted to visitation by long-tongued insects which fly in the dusk. It is often the fact that a particular kind of flower is only visited by one of few kinds of moths, and recent investigations have shown that these latter fly about at definite hours of the night or evening, which times are not varied by weather conditions. It is not, therefore, without significance that different kinds of night-scented flowers attain their maximum fragrance at different hours.

The unpleasant odour emitted by the Carrion Flower of our greenhouses (*Stapelia spp.*) naturally attracts flies—which convey the pollen of these plants—just as effectively as the foetid ivy blossoms in autumn attract the bluebottles that swarm upon them. We might suspect that these were mere accidental associations, the different insects visiting those flowers which happened to emit odours they liked, were it not that scent and flower structure are alike suited to the particular type of insect.

Furthermore, the flower is often the only scented part of the plant, and, if both foliage and flower be fragrant, the scent emitted by the one is quite commonly different from that formed by the other. If these substances were nothing more than waste by-products of the plant's chemical laboratory, we should expect to find them in both flowers and leaves, and those we found in the one we might reasonably expect to encounter in the other.

Even more striking, perhaps, is the almost universal absence of scent from flowers from which the pollen is carried by wind action. Such flowers as the Grasses and Sedges are not only scentless, but devoid of bright colours, and show none of those peculiarities of structure which, for instance, provide an alighting platform for a visiting insect.

Whilst the scent of flowers may, then, perform a very important service for the plant by guiding, if not actually attracting, insects to their blossoms, the fragrance of foliage may be merely due to a waste product, though even this may sometimes attract pollinating insects towards the plant, or, owing to the bitter character

PLATE VII

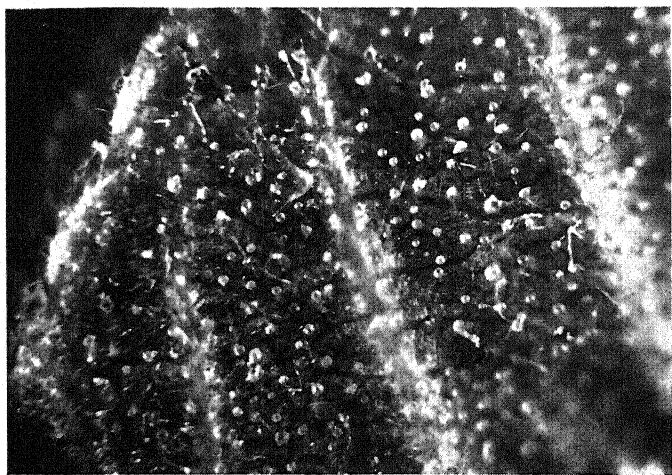
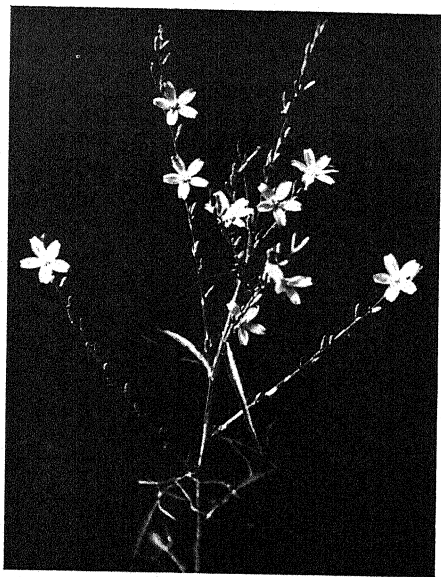


PHOTO-MICROGRAPHS OF SCENT GLANDS ON LEAVES

Above: BLACK CURRANT LEAF with glands in depressions [x 25]

Below: SWEET BRIAR. The glands have the appearance of miniature electric light bulbs on short stalks [x 25]

PLATE VIII



FLOWER-LIKE INFLORESCENCES

Above: *Lactuca Viminea*. Each flower-head bears five strap-shaped flowers that look like petals [x 4]

Below: *Astrantia major*. Each flower-head consists of a number of inconspicuous flowers surrounded by a whorl of petal-like leaves [x 4]

of these ethereal oils, render the foliage distasteful to browsing animals.

The familiar and classical example of the garden Musk which has lost its scent shows that two strains of the same species may one of them produce scent and not the other. The fact that the scented strain has died out and not the scentless indicates that the possession of scent did not, in this instance at least, confer any superiority. Indeed, it would appear to have been associated with a less robust constitution. On the other hand, the strongly scented wild Sweet Briar is, if anything, more robust than some of the almost scentless roses closely allied to it.

If the reason for scent be elusive, the scent itself sometimes evades us. We can most of us appreciate the invigorating richness of the Lime blossom, the delicate fragrance of the Sweet Pea, or the almost oppressive perfume of the Heliotrope, but the scent of a Box hedge in spring or of the flowers of the Spurge Laurel are to the sense of smell what the note of the bat is to the sense of hearing—stimuli near the limit of human appreciation.

Experiments carried out with bees would appear to indicate that they have a sense of smell similar to our own, although their capacity for distinguishing a particular scent amongst a medley of others is probably appreciably greater. Moths and butterflies would appear to be more influenced by scent than bees, but, so far as the experimental evidence obtained shows, the value of scent as a guide to insects visiting flowers is more particularly a short-range one, utilised mainly by the insect in combination with form for distinguishing between different flowers growing together.

Conspicuousness of either individual flowers, where these are large, or of flower masses, where the individual flowers are small, has been shown to be of the greatest importance in guiding the insects. The tiny white flowers of the *Gypsophila* would be very inconspicuous were it not that the inflorescence bears so many. The massed effect of the tiny blooms of the Giant Hogweed or the *Ceanothus* is an advertisement sign of no mean order. In the Dahlias, Sweet Sultan, Scabious, and Sea Hollies,

a whole mass of tiny flowers together resemble a single bloom, so that each aggregate is popularly termed a flower.

This resemblance of the inflorescence to a single flower is most pronounced in the Mediterranean lettuce, *Lactuca viminea*, where each head consists of five bright yellow petal-like flowers, arising from a protective cup of small leaves that resemble a calyx. In the Cornflower and the Guelder Rose the central blooms of each head are alone fertile, the large marginal flowers being sterile, and serving merely to render the inflorescence conspicuous.

Inflorescences of this type are not to be confused with double flowers that are in the nature of monstrosities, in which stamens have been replaced by additional petals and where frequently the essential organs of the flower are completely aborted. Such double flowers (e.g. Double Snowdrops and Daffodils, double Nasturtiums and Clarkias, double Kerria and Prunus) often possess the qualities of increased conspicuousness and longer duration (frequently due to their impotence and incapacity to form seeds); but these assets are usually completely outweighed by the loss in beauty of form of the individual flowers.

The Carnation and the Rose are two of the few flowers which in the double condition have retained in some considerable degree their beauty of shape, but the universal practice of cutting Roses before the flower is full-blown is a tacit recognition that the beauty is in the bud stage before the doubleness is manifest.

It is, in fact, as a sort of advertising device that we must regard the colour of flowers. Of course, it is evident that the effectiveness of colours for advertising the presence of a flower will depend not on how conspicuous it appears to our eyes, but to the eyes of the insect.

The colour sense of bees has been investigated by a number of ingenious experiments which we owe mainly to a German investigator, Von Frisch, who trained bees to visit dishes of honey placed on various coloured papers and subsequently observed their behaviour when the coloured papers were replaced by a series of grey tints. These and other experiments indicate that bees have a somewhat different colour sense from that of

normal human individuals. Bees can distinguish blues and purples on the one hand from yellows and orange on the other. They can also perceive ultra-violet rays that to our eyes are of course darkness. To reds the bee is colour-blind. It is therefore very interesting to find that, when we catalogue the flowers normally visited by bees, the most common colours are blues or purples, but quite frequently yellows. These are, in fact, the colours which render flowers most conspicuous to these insects. If we look at the flower of a wild Pansy, it is either yellow with purple markings or the flower as a whole is partly blue-purple, partly yellow. A garden Forget-me-not has a blue corolla with a yellow centre; and, indeed, amongst flowers of more than one colour the most frequent combinations are yellows or whites associated with blues or purples. Having regard to the colour sense of bees, such association of colours must actually present the maximum contrast to the insect's eye. Moths appear to have a similar colour sense to bees, and the Pheasant's Eye Narcissus, which is a flower visited by moths and which to us appears white with a scarlet trumpet, to the insect's eye probably appears as white and black.

The popular belief amongst gardeners that the colour of the flowers borne on a plant is liable to change if the flowers be visited by insects carrying pollen from another plant of a different colour variety has no support from experiment. Indeed, the colour of the blooms is an hereditary trait, so that a particular colour strain will commonly breed true if the flowers be fertilised either by their own pollen or by the pollen of another individual of the same kind.

But the colour of flowers is produced by a variety of different inherited qualities, and if we are to understand the diversity of tints presented by our Sweet Peas or our Dahlias it is necessary that we should know something of the nature of these qualities.

Colour is, in plants, due to the presence of certain substances, termed pigments, which, when daylight falls upon them, absorb certain of the rays which make up white light and reflect back others. Just as the blended rays of daylight are separated in

the rainbow, so, too, certain of these rays are reflected back to our eyes by the pigments in the petals. These pigments are of various kinds. Some, termed sap-pigments, are dissolved in the watery fluid of the cell sap. They are known to the chemist as 'anthocyanins,' and commonly give a reddish, purple, or blue colour to the petals that contain them. The same anthocyanin may produce a variety of tints according to the degree of acidity of the cell sap, and still more the physical condition of its occurrence. The change in colour of Lungwort flowers (*Pulmonaria*) from pink to blue, or the change from red to purple in some varieties of Rose such as General McArthur, shows that an alteration of the conditions can occur as the flower develops.

Moreover, the different conditions that together determine the colour of a flower may be separately inherited. This is well shown by certain strains of Sweet Peas. There are two strains of the Sweet Pea known as Emily Henderson which can be distinguished by the shape of their pollen. Both have pure white flowers and breed true when, as normally occurs, they are self-pollinated. Yet if we breed these two strains together we do not obtain offspring with white flowers, as we should expect, but with flowers that have a purple standard and blue wings. Each strain possesses the hereditary capacity of producing a certain chemical substance which is by itself colourless: but, when crossed together, we obtain plants which have the capacity to produce both chemical substances, and in combination a coloured product results.

There are also present, dissolved in the sap of most petals, substances known as 'flavones,' which, though they produce a deep yellow colour with alkalis, do not often impart much colour to the flowers in which they occur—partly because they are usually present in very dilute solution, but still more because the cell sap is nearly always acid in reaction. However, the yellow Snapdragons are an exception, and the ivory tint of some white flowers, such as Dahlias, is due to the presence of these substances.

Most yellow, orange, and red flowers owe their colour, not to soluble pigments in the sap, but to coloured substances contained

in bodies within the cell, known as 'plastids,' similar to those which contain the green pigments or chlorophyll.

These plastid pigments are often found in other parts besides the flower, and one, known as carotin, is so called because of its abundance in the skin of the carrot, to which the orange-red colour is due. This substance is of particular interest because, when consumed by man, it yields the substance known as 'Vitamin A,' which is important for adequate nutrition (although a grain of this substance would probably suffice to supply our needs for nearly a year and a half). Cod-liver oil and halibut oil contain considerable amounts of this fat-soluble vitamin, which has been derived by the larger animals from the microscopic floating plants that constitute an important part of their food.

Another common type of plastid pigment is xanthophyll, which is the most frequent cause of the yellow colour of petals. Both carotin and xanthophyll are complex compounds of numerous carbon and hydrogen atoms, whilst the latter also contains oxygen. They are always associated with chlorophyll in green plastids, and when the green pigments undergo decomposition in autumn the xanthophyll and carotin impart the characteristic yellow and red tints to the dying foliage.

The sap pigments also have a complex chemical structure, and, like the plastid pigments, show a considerable range of minor variation; hence nature paints, as it were, with a full palette, and it is scarcely surprising that the diversity of pigments and their various combinations lead to an immense range of tone and tint.

But only flowers which by nature contain both sap pigments and plastid pigments are likely to furnish us with the greatest variety of coloration. More usually the colours of a particular species are due mainly to either sap pigments or plastid pigments, with a consequent limitation of their range of colour.

There is yet one other feature which affects to an appreciable degree the colour value of the flower, and that is the texture of the petal surface. Most ladies are all too familiar with the difficulty of matching colours in different types of material, and

this effect of the character of the surface is strikingly seen when we look at the flower of a Buttercup. Here the pigment is the same throughout the length of the petal, but owing to the change in the nature of the outer walls of the surface of the petal the upper part is bright yellow and shining, whilst the lower part is dull and of quite a different tone. It is because of the diversity of the causes that produce colour that when we breed together different strains of the same species we may obtain the result desired or we may produce plants with flowers of quite unexpected types of colouring.

CHAPTER XII

SEEDS AND THEIR GERMINATION

'In the morning sow thy seed, and in the evening withhold not thy hand: for thou knowest not whether shall prosper, either this or that, or whether they both shall be alike good.'

ECCLESIASTES xi. 6

A SEED is really a structure that encloses and protects the baby plant, which we term an embryo. If you split open a Broad Bean or a Lupin seed, you will find this baby plant occupying the whole of the interior, and consisting of two fleshy leaves, called cotyledons, attached, one on either side, to a short axis. In a Runner Bean seed that has been soaked in water so as to make it swell, you will find that in one direction this axis is curved, and bears small but quite definite leaves at its tip, showing that it is an embryonic shoot. In the other direction you will find the axis is almost straight and pointed, forming a rudimentary root. This little root has its tip quite near a minute hole in the seed coat, so that when the seed is watered this is the first part to receive moisture, and is not unnaturally the first part to swell and emerge from the seed when it germinates. If you split open a Sunflower seed, you will again find the baby plant fills the seed, but the different parts are not so easily recognised.

Similarly, if you open the seeds of either the Guelder Rose (*Viburnum*), Mahonia, or a Castor Oil Plant, you will find you can still recognise a miniature plant with two cotyledons, but here filling only a small space in the seed, the greater part of which is occupied by cells containing stored-up food material in which the baby plant lies embedded. This difference from the Bean or Lupin is less important than it seems.

In all seeds a certain amount of food is placed by the parent plant as a sort of trading capital on which the young plant, when it grows, can earn compound interest. But in some kinds

of plants this food material is absorbed by the baby plant before the seeds pass into the dormant state, whilst in other kinds the food material is not so transferred until after the seed begins to germinate. The difference is comparable to that between a baby going to sleep with a bottle of milk by its bedside, which it will promptly consume on waking, and a baby that drinks its bottle of milk before it goes to sleep. The food is equally there in both instances during sleep, but in the one outside the baby and in the other within.

The effect on our baby plant of absorbing the food before the period of rest is that some part of the embryo in which the food is stored becomes more bulky. This part is usually the cotyledons, which in consequence appear swollen, as in a Walnut, an Acorn, or a Bean. In a Castor Oil seed the cotyledons are thin, because the food material by which the embryo is here surrounded has not yet been absorbed.

With the capital thus provided by the parent plant the embryo obtains the necessary material and energy to grow. The food is very commonly in the form of starch, proteins, or oils. The food value of nuts, the use of Wheat, Maize, and Rice as staple cereals, the exploitation of Flax seed, Cotton seed, Soy Beans, etc., for oil—all these depend upon the food material laid up by the parent plant in its seeds. But the amount of the capital thus provided for the offspring in their struggle for a living varies greatly. A Brazil-Nut, for instance, is almost all food tissue, the little embryo embedded in it being quite small and easy to miss. A double coco-nut weighs some 40 lbs., and is the largest fruit known, but it takes some ten years to ripen, and it is not till long after the seed has germinated that the young palm is weaned from its bottle. The disadvantage of providing so large a birthday present is that the parent is unable to give a start in life to many children. The mere bulk and weight of such fruits furnish an obstacle to their dispersal, and there is no little risk of the seeds germinating too near the parent, and so close together that what they may gain at the outset they lose later from the rigour of the competition with each other.

When you sow a number of different kinds of seeds in the

garden or in the greenhouse, their varied behaviour raises all sorts of questions as to how, when, and why. If you sow Cress seeds, you expect to see a carpet of green in a few days, and you are not disappointed, but if you have sown *Lilium giganteum* seeds you may have to wait for about two years before germination takes place.

Most, actively growing, plants contain about nine-tenths of their weight of water, whilst seeds contain only about one-tenth of their weight of water. It is, therefore, natural that absorption of water is a necessary preliminary to germination; for chemical changes can only go on in solution. Also for these changes to take place sufficiently rapidly the seeds must be at a certain temperature. The rate of chemical change is approximately doubled if we raise the temperature 10° C. (18° F.), and that is the reason why we can usually hasten the process by germinating our seeds in heat.

Oxygen is also a necessity, for without this gas the food materials would not undergo the chemical changes which liberate the energy necessary for growth.

There is a great deal that we do not yet know about germination—more perhaps than we even realise—and it is only by the co-operation of those who germinate seeds that we shall obtain the necessary data to solve the riddles that remain. Every gardener who will make careful observations and notes upon the germination of the seed he sows, with full details as to the conditions, could do something to help.

Thought of from the plant's standpoint, the seed may be regarded as a device by which the offspring is protected, either whilst it is carried away from the parent or during unfavourable conditions. For instance, the annual plants that are found in deserts after a fall of rain could only have persisted through the hot, dry periods in the seed state; or, again, the long-distance carriage of a plant's offspring by winds is only possible because they can resist the drying effect of their journey without injury.

The tolerance of seeds for conditions that would injure any plant in a normal state is nothing short of remarkable. Dry seeds have been known to withstand the temperature of boiling

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water without injury, and Raspberry pips in jam that had been boiled for some time have been known to germinate when placed in moist soil.

In the so-called air-dry state seeds, as we have already noted, are most resistant to extremes of heat and cold. Though the resistance to heat is remarkable, it is far surpassed by their tolerance of cold. Seeds of the Annual Sunflower, of *Funkia*, of *Convolvulus tricolor*, which hails from southern Europe, of Balsam, which is a native of tropical Asia, and of other plants have been subjected for over four days to the temperature of liquid air. None of these seeds showed any indication of impaired germination, despite the very low temperature of between 183° C. and 192° C. of frost which they had endured. The late Sir William Thistleton Dyer even successfully germinated a variety of seeds which had been maintained for from one to six hours by means of liquid hydrogen at a temperature of -250° C., or, translated into terms of the Fahrenheit scale with which the gardener is usually more familiar, about four hundred and fifty degrees of frost. These seeds included large types such as Peas and Marrow pips, as well as the very small seeds of *Mimulus moschatus*. Recently, American investigators have kept various seeds in liquid air for sixty days without any deleterious effects.

Evidently, then, living plant cells which contain little water can withstand very extreme conditions; though the same seeds quickly lose their power of endurance if moistened. Moreover, such resistance is not shared by all seeds equally.

The comparative indifference to external conditions which most seeds exhibit is associated with the fact that the young plant within has become dormant, perhaps in great measure, if not entirely, because of the low water content. That the vital activities are in abeyance is indicated by the experiments carried out many years ago by Romanes in which seeds were kept in high vacua for over a year, or in various gases, including carbon monoxide. It is evident that respiration could not take place under these conditions. Nevertheless, both Peas and Cress seeds yielded over sixty per cent germination after twelve months

in an atmosphere of carbon monoxide, prior to which they had already been for three months in a high vacuum.

The period of dormancy may be short or long, but in most seeds there would appear to be a limit as to the time during which the embryonic plant can remain inactive and still resume activity.

The seeds of some plants, as the gardener knows only too well, must be freshly gathered if we are to hope for good germination. The seeds of Willows at ordinary atmospheric temperatures lose their vitality in about a week, though if kept at a low temperature the period is prolonged; whilst in dry air, maintained at freezing-point, the seeds of the Japanese Willow *Salix pierotii* will germinate after nearly a year, although in air of normal temperatures and humidity they perish within seven days. At the other extreme, seeds of Lotus (*Nelumbium speciosum* and *N. luteum*) were germinated by the famous botanist Robert Brown which were known to be about 150 years old.

The repeated assertions that mummy wheat from the Egyptian tombs will germinate is based on uncritical experiments, and in fact wheat retains the power of germination for at most about sixteen years. Generally speaking, hard-coated seeds retain their power of germinating for the longest periods. The hard seeds of many members of the Pea tribe (Leguminosae) are well known for their remarkable longevity. Lupin seeds can be kept for years and will still germinate, whilst authentic cases of Senna seeds germinating after nearly ninety years are on record.

The causes of this dormancy would appear to be very varied. In some plants it may be said to be compulsory. For instance, in Anemones and many other members of the Buttercup tribe (Ranunculaceae) the baby plant within the seed, instead of having two cotyledons and a recognisable shoot with miniature leaves, as in a Runner Bean seed, is so ill-developed that different parts are not distinguishable. In the Anemone of our woodlands the seed, when shed, contains a baby plant that is a mere group of cells. This grows and develops its different parts during the autumn and winter, and is ready for germination in the early spring. This is true also of the seeds of some Lilies, and

immaturity of the embryo is probably the explanation of the delay in germination of the seeds of *Colchicum*, *Paris*, *Gagea*, *Corydalis*, and a number of other genera.

We can understand that just as a certain measure of structural development is necessary before germination can take place, so there is also a requisite degree of internal or physiological maturity required. The two may develop side by side. But there are plants in which this appears not to be the case, and these are of especial interest to the gardener because of their susceptibility to treatment which will accelerate the necessary physiological changes that are delaying the germination. Good examples are afforded by many members of the *Rosaceae* such as species of Hawthorn (*Crataegus*) *Rhodotypus*, Apple (*Pyrus spp.*), etc. In the seeds of these plants there will be found a fully developed embryo, so far as its external appearance is concerned, but there is considerable delay in its germination.

Numerous experiments have shown that in many seeds delay in germination is a consequence of the fact that the seed-coat is relatively impermeable to either water or air, or both, or even acts by virtue of the mechanical restraint it imposes upon the swelling of the seed contents.

Many leguminous plants, such as Vetches and Everlasting Peas, produce seeds of two kinds—so-called 'soft seeds,' in which the seed-coat is readily permeable and which germinate almost at once, and 'hard seeds,' with relatively impermeable seed-coats, which only germinate after a considerable lapse of time, during which the seed-coat undergoes a change by bacterial action and by other agencies.

If we remove the seed-coat from such 'hard seeds' we can induce germination in as short a period as with the 'soft seeds.' The practice of chipping the seed-coats of Sweet Peas and Cannas is a familiar horticultural procedure to overcome the delay in germination. The abrasion of Lupin, Sweet Peas, and other hard seeds with sandpaper will achieve the same end. It is doubtless the effect upon the permeability of the seed-coat that is responsible for the efficacy of a still more drastic treatment that has been employed with considerable success with some seeds,

namely immersion in strong sulphuric acid for from twenty to thirty minutes, or even longer. This is a method that has been found very efficacious with some of the hard tropical Leguminosae and the stony seeds of many Rosaceae. The seeds of *Cotoneaster divaricata* and *C. horizontalis* benefit by treatment with concentrated sulphuric acid for $2\frac{1}{2}$ hours and $1\frac{1}{2}$ hours respectively.

Even boiling water can be used successfully. Some seed of *Geranium bohemicum* which was thirty-seven years old, and completely failed to germinate under normal conditions, germinated profusely after treatment in this manner. Similarly, hot water will induce germination in old seed of *Abutilon*. In this connection we may recall the profuse germination of Wattle (*Acacia*) seeds after forest fires in Australia.

But the Rosaceous seeds referred to above, though they germinate more readily when the seed-coat is removed, still show a considerable delay. This delay can be overcome by a process known as 'after-ripening' or 'stratification,' in which the seeds are placed in layers in damp sand and kept at a low temperature ($0-5^{\circ}\text{C.} = 32-41^{\circ}\text{F.}$) for a period. For the seeds of *Rosa*, *Amelanchier*, *Pyrus*, and *Cornus florida* a period of after-ripening of about four months has been found efficacious. Apple and Peach seeds which normally require several months of such treatment before they will germinate do so comparatively quickly if the hard covering and skin are first removed, though the resulting seedlings grow at first but slowly. *Cotoneaster* seeds that have been treated with acid still require 'after-ripening' at a low temperature ($1^{\circ}-5^{\circ}\text{C.}$) for three or four months.

The effectiveness of freezing on the germination of the seeds of some alpine, such as *Gentians*, *Diapensia lapponica*, some alpine Campanulas, and *Ribes prostratum*, is very probably due to rupture of the seed-coat in the same manner as our water-pipes burst in frosty weather.

The seeds of some species of *Berberis* (e.g. *Berberis Thunbergii*) germinate freely after subjection to alternations of warmth and low temperature. Henbane (*Hyoscyamus*) seeds have been found to germinate best when subjected to a short period at

just above freezing-point and a prolonged period at 30° C., but with seeds of Thorn Apple (*Datura*) a long exposure to a low temperature of about 15° C. and a short period at 30° C. seems



Rhodotyus Kerrioides

most effective. Such differences between species suggest that the relations between germination and temperature is a very complex one.

The effect of temperature on germinating seeds is, then, not only dependent upon the duration of warmth or cold, but

apparently also on the fluctuations. Quite a number of seeds germinate more readily in a germinator that is subjected to changes of temperature than in one where the temperature is constant. Earlier development and earlier maturation can be induced in some species by subjecting the soaked seeds to a low temperature (from 1° – 3° C.) for about a fortnight. Wheat treated in this way will develop ears a fortnight earlier than a crop raised from untreated seed. The method, which is known as 'vernalisation,' is applicable to seeds that are not to be sown immediately, as if, after treatment, the seeds be dried off, they can be stored and sown later, when the accelerating action will still be exhibited.

That many seeds germinate most readily when the temperature fluctuates need not surprise us, since in nature the temperature during the daytime is normally much higher than at night and it is to the natural conditions that the seeds' mechanism is attuned. This fact does, however, indicate that the hothouse or frame in which the temperature is maintained at a fairly constant level may not be the most suitable place for raising many plants from seed.

The most favourable temperature for germinating Californian Poppies (*Eschscholzia*), Cosmos, Zinnias, and Balsams, all of which are natives of warm regions, is about 68° F. (20° C.), whereas Pansies, which are, in origin, distinctly northern, germinate best at about 63° F. (17° C.), whilst an even lower temperature (*ca.* 59° F.; i.e. 15° C.) produces the most satisfactory results with Papaver. The country and place of origin is indeed a fairly safe but not an infallible guide to the conditions best suited for the germination of seeds.

Attention has already been drawn to the fact that the length of daylight to which a plant is exposed has a marked influence on the time of maturation, but, curiously enough, it has been found that a modification of the method of 'vernalisation' seems to induce indifference in this respect. By subjecting soaked seeds to a moderately high temperature in darkness (20° to 30° C.) for varying lengths of time depending upon the species, it has been found that not only does an earlier development result, but that

the plants mature and flower apparently irrespective of the duration of the daylight to which they are exposed.

Various solutions have been tested to see whether germination can be stimulated by treating the seeds with them. In a very dilute state a number of salt solutions appear to be slightly beneficial; even so dilute a solution as one part of sodium arsenate in 500,000 of water has been found to stimulate germination. An interesting example of stimulation by dilute solutions is that produced by orthophosphoric acid, a substance produced in nature during the decomposition of organic substances but which is also present in the superphosphate of horticulture in the proportion of about 1-5 per cent. This has apparently a remarkably stimulating effect upon the germination of grass seed, which has been increased five to six times by this means.

As long ago as 1600 Francis Bacon experimented upon the pre-treatment of seeds (though of course he did not use the modern term) and chronicles his results in his *Sylva Sylvarum*. It is true that some of the treatments he employed, such as steeping in malmsey wine and claret, were both expensive and ineffective; but it is of interest to note that he obtained more rapid germination when the seeds had been steeped in infusions of various types of manure and water—perhaps because such infusions are usually quite acid in reaction. It is curious that three hundred years should have elapsed before similar methods were again carefully studied.

In nature we seem to have an analogous phenomenon in the fact that the seeds of the parasitic Broom-rapes, which derive their nourishment by attachment to the roots of green-leaved plants, will only germinate in the presence of living roots of the appropriate hosts. This would seem to indicate response to a specific chemical substance.

Another external influence that may have a profound effect upon the germination of your seeds, but which is too often neglected by the gardener, is the influence of light. For example, under normal conditions the seeds of *Phacelia Tanacetifolia* and *Nigella sativa* are inhibited from germinating by light. Others—

as, for instance, *Aquilegia atrata*, *Campanula patula*, *Echium vulgare*, Tobacco, and *Salvia pratensis*—will not germinate at all in the absence of light. Still others—e.g. *Amaranthus caudatus*—germinate equally well in either light or darkness. But by altering the oxygen content of the air, by changing the temperature, or even by removing the seed-coat, it is sometimes possible to modify the way in which a particular kind of seed reacts to illumination.

Seeds which, when freshly gathered, germinate best either in light or in darkness, may, however, become indifferent merely after storage. Fresh seeds of Sweet Alyssum (*Alyssum saxatile*), Burning Bush (*Dictamnus alba*), and the Mullein (*Verbascum phlomoides*) will, for example, germinate better in light than in darkness, whereas freshly gathered seeds of Nottingham Catchfly (*Silene nutans*) germinate better in the dark. But after about two months' storage all these seeds germinate with almost equal readiness in either darkness or in light.

The reaction of the soil, whether slightly or mildly acid, or even alkaline, also influences germination, different kinds of plants showing different responses in this respect. The germination of orchid seeds and some other plants which require the presence of a fungus in the soil to bring about germination, is probably to be regarded as a special case of the necessity for certain stimulating chemical substances to induce germination: since, in appropriate culture media, germination of orchid seeds can be brought about without the presence of the fungal hyphae.

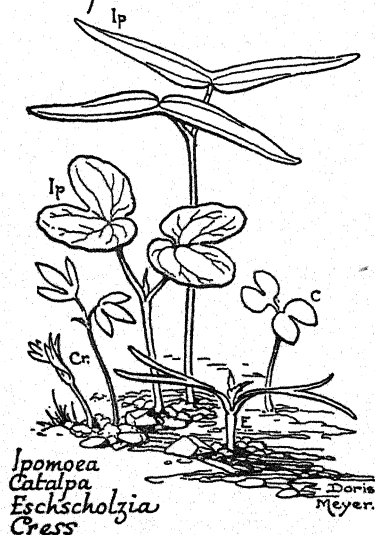
We see, then, that the attempt to give an answer to our question of why and when seeds germinate has resulted in bringing to light the astonishing complexity of the problem and the great amount of variation as between one kind of plant and another in their relation to external conditions. Only with the collective experience of gardeners can we hope to obtain sufficient data respecting the great variety of plants in cultivation to enable the worker in the laboratory to solve the problems that the garden offers for solution.

When we turn to the question of how germination takes place we would appear to be on surer ground, but even here the variety

of behaviour is very noticeable. The cotyledons, or seed-leaves, of many plants come above the soil and serve as the first green leaves—as in Delphiniums, Mustard and Cress, besides many other familiar garden flowers. Other kinds, particularly those in which the food material for the young plant is already within the cotyledons (as in a Broad Bean or a Walnut), do not bring these above the ground, so that they do not function as green leaves but merely as storehouses of food.

This difference in the behaviour of the cotyledons, though characteristic of the different kinds of plants, is not really very fundamental, since closely allied plants like the Runner Bean and the French Bean behave differently, although in both these the food is stored in the cotyledons. Seedlings of the French Bean do sometimes germinate with the cotyledons below the surface, as in the Runner Bean, but usually they are brought above the ground, turn green, and help the young plant to make more food.

*Seedlings with unusual
Cotyledons*



*Ipomoea
Catalpa
Eschscholzia
Cress*

As the conditions in which these first leaves, or cotyledons, develop within the seed are very similar in different kinds of plants, and the purpose they serve is the same, it is not a matter for surprise that to superficial observation the cotyledons of most seedlings look very much alike. That it is the uniformity of their environment and function to which their similarity of form is related can, I think, be inferred from the still more uniform character of cotyledons that remain below ground. But when we germinate seeds of related plants we shall find that their cotyledons usually resemble one another more closely than those of seedlings

belonging to quite different families. The almost round cotyledons of *Salvia*, *Monarda*, *Dracocephalum*, etc., with the stalk attached in a notch-like depression, is a feature of most members of the Deadnettle family (Labiatae), whilst the pointed seed-leaves of *Delphiniums*, *Globe Flowers*, *Adonis*, and *Nigella* are almost equally characteristic of other members of the Buttercup family.

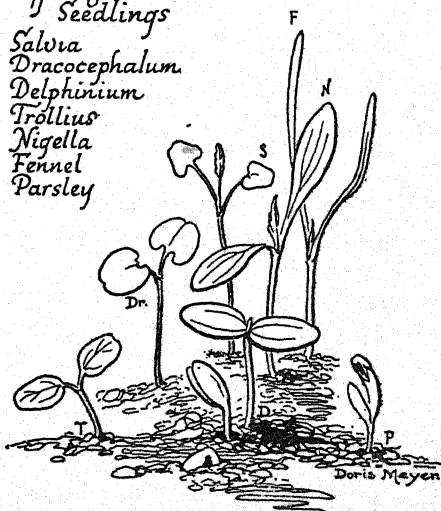
Sometimes, however, cotyledons that come above the ground differ appreciably from the simple form we are accustomed to. The three-lobed cotyledons of the garden Cress would strike us as unusual were it not for their extreme familiarity. The cotyledons of *Eschscholzia*, *Catalpa*, and *Morning Glory* (*Ipomoea*) are bi-lobed, the lobes of the first being quite narrow and slender, whilst the cotyledons of some *Ipomoeas* are shaped rather like a butterfly with expanded wings.

But usually the cotyledons are quite simple in form, no matter how deeply divided and feathery the leaves of the adult plant. The familiar seedlings of *Fennel*, *Parsley*, and *Carrot* all have the simple strap-shaped cotyledons that characterise most members of the family Umbelliferae, yet the Lime-tree, which has simple heart-shaped leaves, produces seedlings with cotyledons that are deeply cleft into five to seven lobes.

Because of their general similarity, too little attention has been paid to the differences that cotyledons do show, and until horticulturists have added considerably to our knowledge in this respect we can scarcely hope to be

Types of Seedlings

Salvia
Dracocephalum
Delphinium
Trollius
Nigella
Fennel
Parsley



able to generalise as to the significance which is to be attached to such differences as do occur.

Much more important and of much greater practical significance are the differences in the times of germination.

In writing of dormancy we have already drawn attention to the long delay in germination of the seeds of some plants unless we apply artificial methods, such as treatment with acids, or employ the procedure known as stratification. It will be worth while considering such instances from the point of view of the time of germination under natural conditions.

The seeds of some flowering shrubs, such as the Myrtle, Lilac, Clerodendron, or Honeysuckle, usually germinate in the first year after sowing; but there are a number of garden trees and shrubs which commonly require two years before the seeds germinate, as, for example, those of Magnolia, Witch Hazel (*Hamamelis*), *Exochorda*, and *Rhodotypus*. If we sow freshly ripened seeds of the Laurestinus (*Viburnum tinus*), some of these may germinate in the first year, but most of them will probably germinate in the second year, some still in the third, fourth, or even in the fifth year. More frequently in species where there is appreciable delay, some of the seeds will germinate in the first spring after sowing and the remainder the spring following.

It has been found that the seeds of some plants will, under natural conditions, germinate more freely after a severe winter in which the seeds had been subjected to low temperatures. From observations of this character the practice of refrigerating some seeds before sowing has been evolved. Of those which germinate much more rapidly and in much greater numbers after low temperature treatment one may mention the Paper Birch, *Sambucus canadensis*, *Rhododendron lapponicum*, various species of Whortleberry (*Vaccinium*), *Iris versicolor*, and *Potentilla tridentata*. Some Gentians, also, respond to this treatment, whilst the seeds of other gentians germinate more readily when not subjected to low temperature. Amongst seeds for which such treatment appears essential in nature may be mentioned *Kalmia polifolia*, *Pyrus americana*, and *Cornus canadensis*, of which the seeds unless frozen usually fail to germinate at all.

It may seem remarkable that seeds which have for their purpose the reproduction of the species should under natural conditions appear to germinate with such difficulty. But the delay in germination is often a necessary consequence of the adequate protection for the young plant within the seed which is essential to permit of its safe carriage away from the neighbourhood of the parent.

The seeds of annuals show similar differences in the time of germination, although there is rarely the pronounced delay that one meets with in trees and shrubs unless the seeds become buried in the soil, where they may retain their vitality for many years, to germinate when brought to the surface.

The seeds of Love-in-the-Mist (*Nigella*), if allowed to ripen and fall to the ground, will germinate in profusion in the autumn, and the seedlings survive the winter quite well provided the soil be light. Plants that behave in this way may be termed winter annuals. Quite frequently, however, germination occurs only in the spring, as, for example, some annual *Linarias*, and such may be called summer annuals. The latter pass the cold winter season in their most resistant state—namely, as the seed—whilst the former usually attain this stage in their life-history before the summer drought. Each type of germination has its advantages and disadvantages according to the degree of tolerance of the species for cold or drought.

Most frequently, whether the seeds germinate in the autumn or the spring, all the seeds of one plant tend to germinate at once—that is, they are approximately simultaneous. There are, however, many kinds of plants whose seeds only germinate gradually. In some species this is so marked that we can speak of the germination as being continuous, or, if the seeds germinate at intervals, as intermittent. A striking example of the latter is the annual Rock Rose, *Helianthemum guttatum*, the seeds of which germinate at intervals over a period of some months beginning in the autumn and extending late on into the following spring. This species is actually rather susceptible to hard frost, and so, when the winter is severe, only those seeds which germinate in the late spring produce seedlings which survive,

150 SEEDS AND THEIR GERMINATION

the earlier batches having been killed off by the frost. If, however, the winter be mild, the seedlings which come up in the autumn survive, and naturally make bigger plants than those which do not start growth till the following year.

CHAPTER XIII

WEEDS

'We are accustomed to see men deride what they do not understand.'

GOETHE

WHAT is a weed? Well, it all depends upon the point of view. The plant which you and I tend with zealous care and rejoice to see producing offspring is perhaps, in its native home, regarded as a pest. The little French Marigolds which for more than three hundred years have brightened our borders, and which we do not hesitate to call garden plants, would be regarded by the Mexican as mere weeds of waste ground.

The early settlers in New Zealand who introduced the English Sweet Briar certainly considered it a most desirable shrub and planted it everywhere, but in 1800 it was one of the three plants officially declared to be a noxious weed that must be treated as an enemy and destroyed. So, too, the New Zealanders who now regard the Broom as a pest doubtless lavished on it similar care to that which they once bestowed on Blackberries and rabbits. The erstwhile garden plants have become weeds.

Whilst on the one hand some of our most prized garden plants are looked upon as weeds in their native homes, others which the unsuspecting beginner starts by cultivating with solicitude—such as the fragrant Winter Heliotrope (*Petasites fragrans*), the Scarlet Hawkweed (*Hieracium aurantiacum*), the beautiful Blue Sow-Thistle (*Mulgedium Plumieri*), or the yellow Lupin-like *Thermopsis montana*—he ends by bitterly reproaching, and refers to them as 'growing like weeds.'

We can in fact only define a weed, *mutatis mutandis*, in terms of the well-known definition of dirt—as matter out of place. What we call a weed is in fact merely a plant growing where we do not want it. If we think of the many plants that we consider to be weeds it is evident that they have little in common beyond being something of a nuisance. The stigma in our minds

*Thermopsis Montana*

depends partly on our personal preferences, but still more on the conditions in our garden. The plant which we consider to be a weed, and which with us soon gets out of hand, may nevertheless be prized by a fellow gardener whose soil and situation is different, and who may never have experienced any but the most rigid decorum in its behaviour.

When we try to think what exactly we imply by referring to any plant as a weed, we soon realise that though all weeds are plants that grow where we do not want them, those which we consider most deserving of that term of opprobrium possess a capacity of coming up from seed, or a rapidity of spread by vegetative growth, that renders difficult the task of coping with their natural increase. In any plant we prized highly we should consider this a most admirable and desirable trait.

Such characteristics of 'weeds' are not without their interest, and, since weeds, like the poor, are always with us, the quality of mercy, which we must often perforce exercise towards them, is less strained if we come to have a sympathetic interest in their mode of life. Furthermore, to study them is in the nature

of an appropriate revenge for their insistence upon our notice.

Many of our commonest, though by no means our worst, weeds are annuals. The Shepherd's Purse, the hairy Cress, and Ivy-leaved Speedwell, which appear in the spring; Petty Spurge, in the autumn; or Groundsel and Chickweed, all the year round—these are a few of the annual weeds which soon carpet the freshly turned-up soil. They are indeed characteristic of cultivated ground generally, and this feature, together with their absence from situations where vegetation forms a continuous carpet of growth, suggests one feature which they have in common—namely, a very limited toleration of competition with other plants. The cultivation of soil by man necessarily destroys the perennial species, or at least checks their growth and thus provides the bare areas where these annuals can flourish.

When the first cultivators of soil—men of the Neolithic age—came to these islands from the Continent, they not only increased the area where annual plants could flourish so that the native plants of land-slides, moraines, young dunes, and other naturally disturbed soils had fresh habitats to occupy, but the Neolithic men themselves probably introduced weed seeds from the regions whence they came, as impurities in the crop seeds they brought with them. The Fool's Parsley (*Aethusa cynapium*) and the Fumitory (*Fumaria officinalis*) may perhaps have come to us in this way, since remains of both these weeds first appear in deposits of Neolithic age.

Since the time of Neolithic man the areas of cultivation and other disturbed soils created by man—such as rubbish shoots, waysides, and the like—have been the locus of many introductions from overseas, some of which have only been temporary colonisers whilst others have persisted to the present time. The succession of human invaders into Britain, from prehistoric times onwards, doubtless facilitated the introduction of 'weeds,' and this influence of man's activities as an agent of dispersal is shown by the fact that the more recent arrivals amongst our weed population, such as the Pineapple Weed (*Matricaria discoidea*) from Oregon, or the small-flowered Balsam from

Russia (*Impatiens parviflora*), are from regions with which frequent intercourse is of comparatively late date.

Annual weeds will often appear on soil which is disturbed where there have been no weeds of the kind for many years. Their buried seeds have in fact remained dormant in the soil, and germinate only when brought to the surface. The seeds of some of our common weeds, such as the Curly-leaved Dock (*Rumex crispus*), the large Plantain (*Plantago major*), and the Black mustard (*Brassica nigra*), are known to be capable of germinating after having been buried for forty years, and seeds of Shepherd's Purse and Chickweed have germinated after thirty years' burial. How numerous are these buried seeds, and how uniformly distributed in the soil, is indicated by the sheets of Poppies and Charlock which appeared upon the soil disturbed by the shells and trenches during the war. Actual counts of Poppy seedlings germinating from seeds in the soil taken from an arable field have shown that over two thousand five hundred Poppy seeds may be present in a square foot of soil.

When the price of wheat fell at the end of the Napoleonic wars many cornfields were laid down to permanent pasture, and in most instances have remained in that condition to the present day. But some few such again became converted into ploughland, whereupon a crop of weeds once more appeared, arising from the seeds that had been buried for nearly a century.

It is the presence of such seeds, buried but still capable of germination and growth, which is one of the difficulties that the gardener has in the cleaning of ground from its weed flora. We repeatedly till some piece of soil, and we do not allow any of the weeds to 'go to seed,' yet we still find Poppies and Shepherd's Purse, Groundsel and Chickweed, coming up year after year; and this will continue till the supplies of buried weed seeds are exhausted. However, the more we cultivate the ground the more quickly will the buried seeds be brought to the surface where they can germinate; so that the soil becomes cleaned more expeditiously.

If we let a single plant produce ripe fruits the supply of dormant seed will become renewed. It is therefore of some interest to

know how many seeds these little annuals will produce. How bad an effect will it have if we allow one Plantain, one Chick-weed, or one Poppy to ripen a crop of seeds?

We all recognise the need for cutting down Thistles and Dandelions before they begin to ripen their fruits, but, since we cannot always be attending to every part of our garden simultaneously, we must perforce weed each portion of the garden at longer or shorter intervals. The better kept the garden—or, in other words, the shorter the intervals between successive weedings of the same area—the less chance will there be of new seeds ripening and being shed on to the soil before the ground is again cleared. Or, looking at it from the standpoint of the plant, the shorter the period of growth necessary, after germination, before a particular weed can flower and fruit, the greater will be the chance of its survival; since it is more likely that it will have shed its seeds before the area where it is growing is again weeded.

Many of our commonest weeds can produce flowers and fruits in a very short period, and there can be no reasonable doubt that their survival and success as weeds is in no small measure due to this inherent quality of rapidly coming to maturity.

So we see that it is not merely a matter of interest, but of considerable practical importance, to know what sort of a crop of seeds our weeds yield, and how long a time must elapse in each type between seed time and harvest. A really large plant of Shepherd's Purse, growing in a garden, was found to bear as many as six hundred and fifteen seed-pods. Quite a small plant will bear over fifty, and a moderate-sized individual will produce over three hundred. The seeds were counted in over a hundred of the seed-pods, selected at random so as to obtain a fair average. The number of seeds in each pod was found to range from three to as many as thirty-four, but the average number of seeds was sixteen or seventeen. A medium-sized plant of Shepherd's Purse then will quite easily shed over five thousand seeds on to the soil, and of these almost all will be found to be capable of growth.

The scarlet field Poppy will produce from ten thousand to

sixty thousand seeds on a single plant, whilst a large Dandelion plant may easily produce over twelve thousand fruits. Such potential families appear prodigiously large, but they are small compared with the number of seeds formed by a large Mullein or a Foxglove, which may easily yield nearly a million seeds.

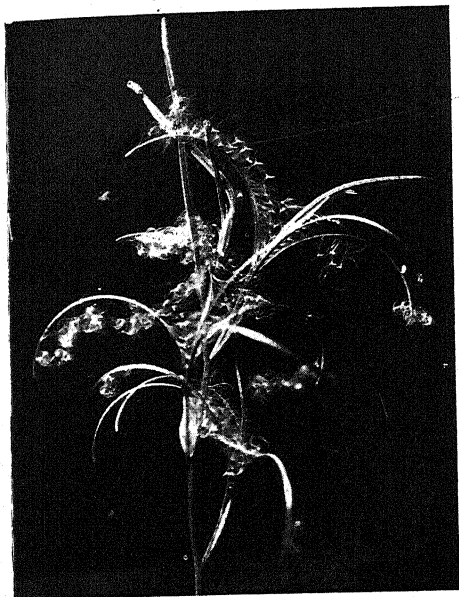
The larger plants, with their huge fertility, are, after all, readily seen and easily uprooted before the fruiting stage. But the smaller plants, though producing far fewer seeds, are readily overlooked, and so the four or five thousand seeds which are formed by a fair-sized Chickweed or Groundsel are quite sufficient not only to maintain the plant in our gardens, weed we never so carefully, but ensure that the weed will increase in numbers, and occupy any suitable ground left vacant, unless we exercise the greatest vigilance.

Even though the Groundsel and Chickweed have comparatively small families, they fully make up for this by the precocious manner in which they attain maturity and produce seeds, sometimes within six weeks of germination. The poorer and drier the soil the fewer seeds they will form, but under these conditions the plants bloom earlier, the fruits ripen much sooner. Hence it is that these annual weeds can often pass through several generations in a year. Is it to be wondered at that the Chickweed is always with us, or that the Shepherd's Purse and Groundsel appear on almost any soil that we may dig up?

The seeds of the Shepherd's Purse and the Ribwort or Black Plantain are sticky when moist, and for this reason adhere readily to spades or any other tools with which they come in contact. In this way, or in the mud on our boots and gardening implements, the seeds are carried from one part of the garden to another, and from garden to garden. So efficacious is this carriage by man of the seeds of the Ribwort (*Plantago major*) that it earned for it the name of White Man's Foot, bestowed by the North American Indians.

Who that has the little Hairy Cress (*Cardamine hirsuta*) as a weed in their garden—and their number is legion—can have failed to notice the way in which the seed-pods explode if we touch the ripe fruits as we weed. The coverings of the pods, as

PLATE IX



Left: WILLOW HERB

Showing seeds, each with
a parachute of hairs, escap-
ing from the bursting cap-
sules [natural size]

*Below: FRUITS OF
SOLDIER'S PRIDE*

Showing on the right a
feathery parachute in side
view and on the left the
parachute from above [x 5]

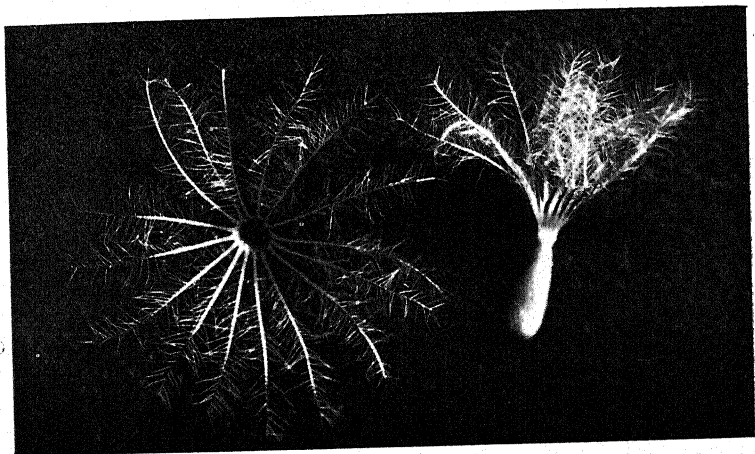
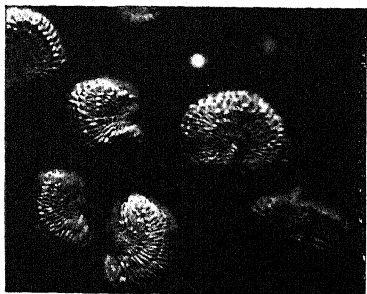


PLATE X



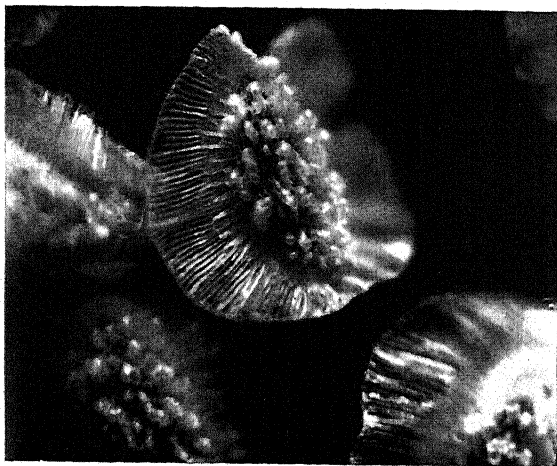
SEEDS OF ORIENTAL POPPY [x 20]



SEEDS OF *Silene nutans* [x 20]



SEEDS OF FOXGLOVE [x 20]



WINGED SEEDS OF NEMESIA [x 20]

they dry, shrink, and a tension is set up, so that each side of the pod coils up instantaneously like a spring, flicking out the seeds into the air around. Even in still air the seeds are shot out to a distance of about a yard from the parent plant, so that when there is the slightest breeze blowing the seeds are even more effectively scattered.

The fruits of the Sow-Thistle, Dandelion, Groundsel, Cat's Ear, Soldier's Pride (*Centranthus ruber*), and many others are carried by the little parachutes which surmount them. So too the seeds of Willow Herbs and Willows have hairy appendages. Borne up by air currents, sometimes to considerable heights, such fruits and seeds may travel many miles before they come to earth, and their ubiquity is shown by the way in which these plants will appear high up on the old joints of the masonry of church towers and steeples, or colonising the vacant plots in the heart of our cities or the neglected areas of our slums. We need not, and, indeed, cannot, question the efficacy of the means of dispersal of the seeds and fruits of our common weeds, and so will scarcely be surprised that they appear whenever and wherever we render conditions suitable for their growth.

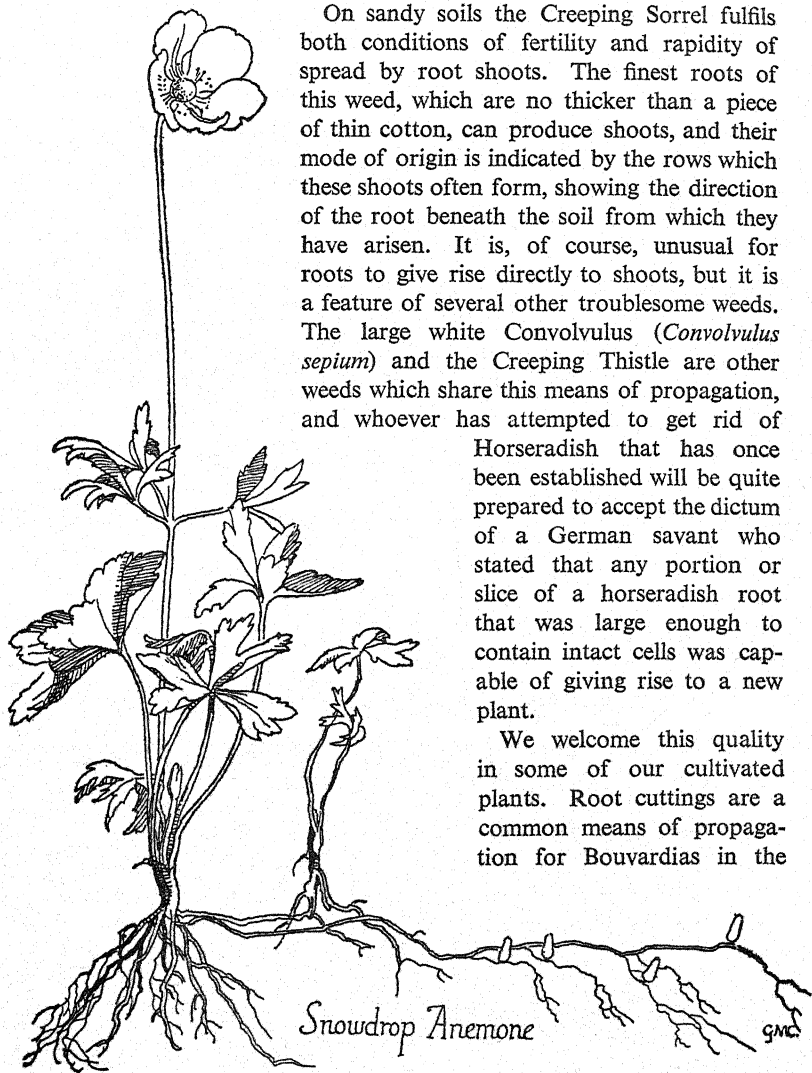
But if the annual weed is ubiquitous, it is usually harmless in comparison with its perennial counterpart. If we were asked to make a list of the worst weeds in our gardens, most of us would place perennials at the head. Indeed some of the greatest pests are plants that may rarely produce fertile seed. The pretty Yellow Toadflax that looks so cheerful and harmless in the late summer is, as many a gardener knows to his cost, one of the worst of pests. It is true it can produce some thirty thousand seeds in a single season, but very few of these seeds are capable of germinating—sometimes less than one in a thousand is viable. Yet the plant is a success because, when once a new individual is produced, the roots extend down and outwards, and every little rootlet is capable of sending up shoots, so that from a single original plant over two hundred shoots may be formed in the second season. Luckily owing to its poor production of fertile seeds, Yellow Toadflax is not very widespread as a weed, but where it has obtained foothold it is well-nigh ineradicable.

If it ever produced a more fertile strain, one more woe would be added to the gardener's trials.

On sandy soils the Creeping Sorrel fulfils both conditions of fertility and rapidity of spread by root shoots. The finest roots of this weed, which are no thicker than a piece of thin cotton, can produce shoots, and their mode of origin is indicated by the rows which these shoots often form, showing the direction of the root beneath the soil from which they have arisen. It is, of course, unusual for roots to give rise directly to shoots, but it is a feature of several other troublesome weeds. The large white *Convolvulus* (*Convolvulus sepium*) and the Creeping Thistle are other weeds which share this means of propagation, and whoever has attempted to get rid of

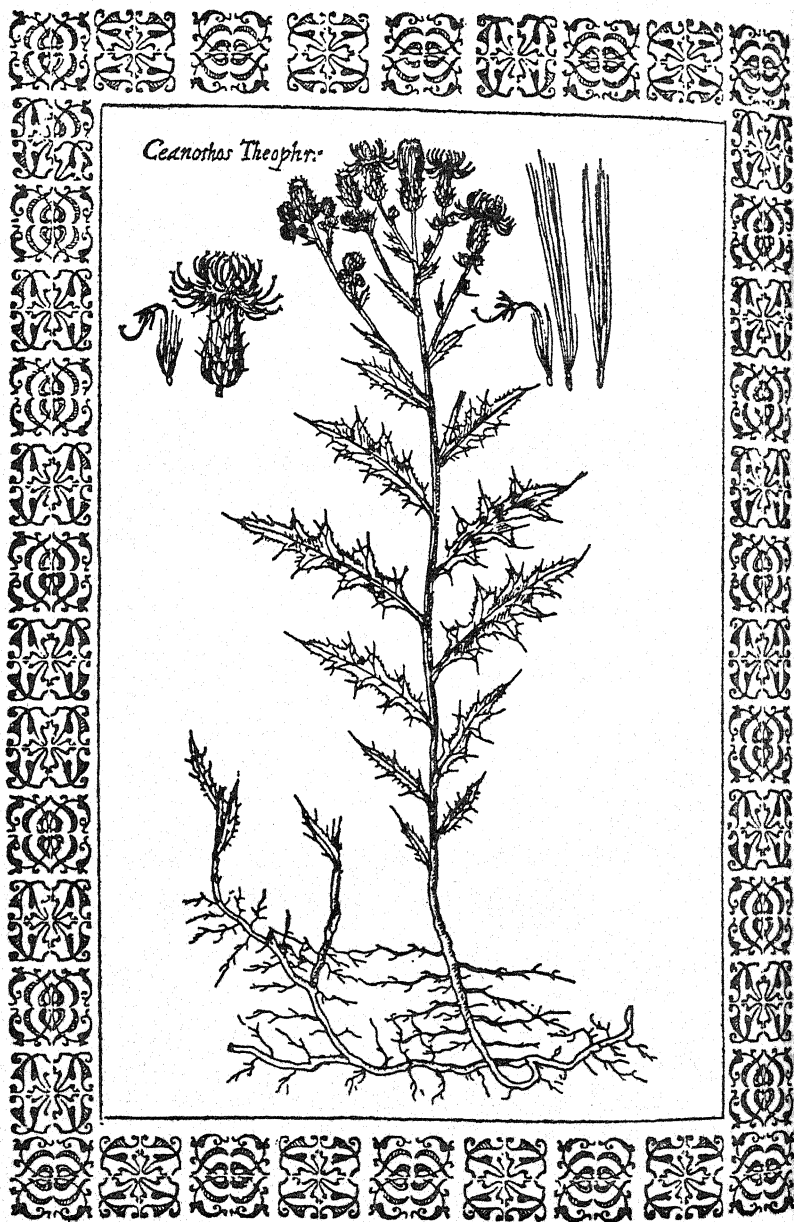
Horseradish that has once been established will be quite prepared to accept the dictum of a German savant who stated that any portion or slice of a horseradish root that was large enough to contain intact cells was capable of giving rise to a new plant.

We welcome this quality in some of our cultivated plants. Root cuttings are a common means of propagation for *Bouvardias* in the



greenhouse. In the vegetable garden we employ this method for multiplying Sea Kale, whilst amongst the plants of the flower garden the Californian Poppies (*Romneya Coulteri* and *R. trichocalyx*), the Bear's Breech (*Acanthus mollis*), *Anchusa italica*, and *Anemone japonica* can be multiplied in this way without difficulty. The Snowdrop Anemone (*Anemone sylvestris*) and *Euphorbia cyparissias* are plants which, though grown in the flower garden, may on light soils readily become a nuisance, owing to the facility with which they produce shoots from their roots and hence soon extend their area beyond that allotted to them. The real trouble in cultivating such plants is that, since the shoots arise from the roots, the spread of the plant has already taken place before we realise how large an area it has occupied.

This is true also of those plants, which are far more numerous, that form horizontally spreading underground stems, the tips of which sooner or later grow up to form a leafy shoot. Such 'rhizomes' may only grow a short distance each year, as in the Solomon's Seal or the newer kinds of Michaelmas Daisy, so that we realise the rate of spread and can readily keep such plants within bounds. But many rhizomatous plants are capable of an astonishing radial growth each year, so that the new shoots arise some distance from the parent stems, and we are unaware of the spread that has taken place underground until the leafy shoots appear—it may well be amongst those of some choice neighbour a yard away. Some of the worst weeds known to the gardener spread secretively in this manner. The Ground Elder (*Aegopodium Podagraria*), the Rosebay Willowherb (*Epilobium angustifolium*), and the Coltsfoot, if they once become well established, are for this reason well-nigh ineradicable weeds. The rate of spread is naturally dependent on the soil texture, for the heavier the soil the more energy has to be expended by the parent plant in forcing its rhizomes through the soil: but even in heavy clay soils underground shoots of the Ground Elder have been known to grow from two to three feet in length in a single season, whilst the Rosebay Willowherb will sometimes form annual increments of several yards in length.



CREeping THISTLE, from the *Herbal* of Fabius Columna, 1616.

There are garden plants which, like the Rosebay Willowherb, we prize for their beautiful flowers, but which unfortunately spread almost as rapidly, and are dangerous to plant in a garden unless we are fully alive to their characteristics. The Winter Heliotrope (*Petasites fragrans*), the Bladder Herb (*Physalis Alkekengi*), the Scarlet Hawkweed (*Hieracium aurantiacum*), *Campanula rapunculoides*, *Helianthus* Miss Mellish, *Thermopsis montana*, the Blue Sow-Thistle (*Mulgedium Plumieri*), and *Polygonum cuspidatum*, are all liable to become intolerable weeds, and the gardener who is attracted by the undoubted beauty of their flowers must beware of introducing them except into the semi-wild garden.

Less insidious are those plants which spread rapidly above ground, though the Creeping Buttercup and Cinquefoil can be sufficiently troublesome; and even amongst cultivated species the tyro must be careful where he plants such as the lesser Periwinkle, the Rose of Sharon, *Acaena Buchananii*, *Helxine Soleirolii*, and *Veronica filiformis*. The Snowberry (*Symphoricarpos racemosus*) and the Stag's Horn Sumach (*Rhus typhina*) are typical examples of shrubs that often become weeds through the too free production of 'suckers,' which are a particular kind of woody underground shoot that remains attached to the parent for a period of years.

Other garden plants there are which come to be regarded as weeds because they produce seed and germinate too freely. But whereas plants that spread by vegetative means and are a pest in one garden are commonly troublesome in other gardens also, those plants which depend upon seed for their propagation are much more susceptible to differences of soil and situation. All of which shows how desirable it is that we should use the opportunities which the garden affords us of studying the behaviour of each kind of plant we grow, and make careful notes of such matters as the rate and manner of spread, which may even vary in different parts of the same garden. In this way a mass of data could be accumulated in respect to the biology of garden plants that would not only be invaluable to the cultivator, but would also add materially to botanical knowledge.

The use of chemicals to control weed pests has now become an acknowledged agricultural practice. In the garden, lawn sand, a mixture of ammonium sulphate, a little iron sulphate, and sand, has long been employed to check the growth of weeds in grass. A double advantage is secured when the substance which is injurious to the weeds has a manurial value after the ground has been cleaned. Such substances are ammonium sulphate, calcium cyanide, kainit, and lime. But wholesale destruction cannot usually be accomplished in planted ground, and hand cultivation is the simplest means of eradication.

Further, it must be remembered that weeds may not only be deleterious by their direct influence, but may indirectly injure the plants we cultivate by serving as host plants on which various pests may survive in the temporary absence of the appropriate cultivated crop.

CHAPTER XIV

THE CHANGING YEAR AND THE CHANGING DAY

'To be woven eternally on the loom of perpetual change.'

F. MANNING. SCENES AND PORTRAITS

THE CYCLE of the seasons, with their never-ending variety, their constant innovations, is certainly not the least of a garden's charm. The periodic rhythm gives us at once the pleasures of anticipation and the added interest of change. A repetition that is like meeting an old friend in a new mood. There is neither beginning nor ending to the gardener's year—'only recurrent patterns on a scroll.' But the patterns that recur are never quite alike.

This kaleidoscope of plant life is naturally associated in our minds with the periodicity of climatic change. Indeed, though summer be connected in our thoughts with foliage and flowers, winter with fallen leaves and the dark tracery of bare boughs, still more is summer linked with thoughts of sunshine and warmth, and winter with frost and snow.

But though many plants exhibit similar changes at approximately the same season, there are others which undergo similar transformations at different times, or different changes at the same time—in other words, it is not just a simple relation between cause and effect. The climatic change is but one influence, and, great though it be, the individuality of the plant may be greater. The oncoming of winter that finds so many plants dormant with bare stems, finds others still active and wearing almost their summer cloaks of green. The native Spindle sheds its leaves, but its Japanese relative, *Euonymus japonicus*, retains them. The genera *Berberis* and *Viburnum* furnish other familiar examples of allied deciduous and ever-green shrubs.

The winter is not merely a season when the soil is liable to be cold, perhaps actually frozen, but it is also often a period of

high winds. So, on a sunny day especially, loss of water from the surface of the plant is likely to be considerable, whilst the possibility of making good such loss from the soil may be little or nil.

In most native English trees and shrubs the difficulty is circumvented; owing to the shedding of their leaves with the advent of the cold season. With this loss of foliage the large evaporating leaf surface disappears, and only a skeleton of stems and branches remains, the whole surface of which is not only small in comparison but is covered, even to the scars whence the leaves were shed, with a thin layer of cork relatively impermeable to water vapour. Even the buds are clad in an armour of scales that check the loss of water from the rudiments of next spring's shoots. The herbaceous perennials achieve the same economy of water during the winter by the entire loss of their overground shoots, so that only the well-protected parts beneath the surface of the ground remain. The annuals, of course, pass this adverse period, in the most protected state of all, as the seed.

Similar features are found to characterise many of the plants that are native to regions where there is no cold season, but where there is an adverse period due to prolonged drought. Thus it is that the change in transpiring surface of some warm-climate shrubs accompanying the changing year enables them to survive our winters—as, for instance, *Evodia hupensis*, a beautiful deciduous shrub from central China, native of a region with a latitude comparable to that of Egypt. The beautiful Fuchsia Gooseberry (*Ribes speciosum*), which comes from California, though deciduous, has a rhythm that is not quite adjusted to our seasons, since both the leaves and flowers are liable to expand too early and to be damaged by late frost, except in protected positions.

It is clearly a matter of considerable interest and importance for the gardener to know what influences affect the times at which deciduous plants shed their leaves or develop new ones. If we could hasten the one or delay the other, the susceptibility to frost injury of many trees and shrubs could be minimised.

The autumn leaf fall is prepared long before it actually takes

place. There is a definite layer of separation at the base of the leaf-stalk, the presence of which is often recognisable in the green leaf. It is this layer which produces the corky covering of the scar. Other influences beside the onset of the cold season—as, for instance, a severe drought, or injurious fumes—may also bring about activity of this layer and a shedding of the leaves even in the height of summer.

Deciduous shrubs and trees when grown in the uniform warmth and moisture of tropical regions may still shed their leaves, but in an irregular manner, so that different branches of the same tree may show bare twigs, expanding buds, and fully mature foliage, all at the same time. The rhythm remains, but there is no regulating influence of a seasonal change in climate to synchronise the events.

The individuality of the plant is further shown by the way in which a hedge of young Beech-trees, or old Beeches, if they be kept well trimmed, will retain their leaves throughout the winter, although these all turn brown.

Illumination, temperature, supply of nutrient salts—all play their part in influencing the time of leaf development, as well as of leaf fall, in varying degrees according to the species involved. So it is that a shrub liable to suffer injury by late frosts may not benefit, but actually be harmed, by too sheltered and sunny a position, or by too copious a supply of nutrients, since the more exposed and less well-nourished individuals, which in consequence come into leaf later, escape the injury which the more precocious individuals suffer.

The period of development of new leaves is quite evidently a characteristic of the particular kind of plant. The wild Honey-suckle begins to form its new leaves in January—not very robust-looking ones, either. The Birches, the Bird Cherries, and Forsythias in mid-April, the Service-tree not till the middle of May. In the borders, the Grape Hyacinths and the Geums have already begun to develop new leaves in the autumn, but the majority of herbaceous plants come into new leaf in spring, though by no means simultaneously.

If we grow different varieties of the same species, these will

occasionally be found to develop their new leaves at very different times, just as we also have late and early strains with respect to flowering season. It has been shown that for some of these, and it is probably true for most, the tendency to develop the leaves early or late is an inherited characteristic, the qualities of the parent plants in this respect being shown by the seedlings raised from them.

Perennials may exhibit a change, with regard to the period of formation of the new leaves, with increasing age. The Maiden-hair-tree (*Ginkgo biloba*) and the Vine both tend to develop their new leaves at an earlier and earlier date as the age of the plant increases, whereas the Horse Chestnut appears to exhibit a delayed expansion of the foliage as the tree advances in years.

In the garden nothing is more striking than the gradual wave of green which the spring evokes, but perhaps even more remarkable is the diversity of times at which plants flower. Just because it is so obvious a fact, it is apt to be overlooked, or its significance ignored. There is scarcely a month of the year when we cannot have a plentiful supply of blossom even in the open.

If we consider the wild plants of any region, it is true there is usually one season at which more kinds are to be found in bloom than at any other. The greatest number of the wild flowers of Britain are to be found in flower in the month of July, when it would probably be possible to find about fourteen hundred different species in bloom at the same time in different parts of the country. In June and August there would probably be found about a thousand, less than half that number in May and September, and only a few in January or December, if we except stray blossoms of plants that we cannot count upon to bloom at that season.

But, since most plants maintain their individual rhythms with but little alteration when we transfer them from foreign climes to our own, we can maintain a better seasonal balance of flowering in our gardens by judicious selection. Even in December, though there be a paucity of kinds, we can multiply individuals of the Christmas Rose (*Helleborus niger*), of *Iris*

alata and *Vinca difformis*, which, though all from the south of Europe, endure our inclement winter with impunity, and can normally be relied upon to give us flowers at Christmas if not before.

In January we look forward to the blue blossoms of the Algerian *Iris unguicularis*, the purple flowers of *Primula Juliae* and *Saxifraga ligulata*, and the golden carpets of the Winter Aconites, with their green Elizabethan ruffs; whilst our shrubberies are already brightened by the dainty yellow flowers of the Chinese *Hamamelis mollis*, and the scented blossoms of the Japanese Allspice (*Chimonanthus fragrans*). On our walls the Yellow Jasmine from China has perhaps been in bloom some weeks.

February brings a wider choice with the Snowdrops, Crocuses, *Adonis amurensis*, *Cyclamen cilicicum*, and *Saxifraga apiculata*, the violet-like fragrance of *Iris reticulata*, and the heavy odour of the Winter Heliotrope (*Petasites fragrans*). From the shrubbery there is wafted the penetrating scent of the Chinese *Viburnum fragrans*, and of our own native woodland *Daphne mezereum*, whilst the vivid yellow of the Cornelian Cherry (*Cornus Mas*) suggests sunshine on the dullest day. With the advent of March the white of the Snowdrops and the gold and purple of the Crocus flowers have given place to the blue carpets of the Siberian Squill (*Scilla sibirica*), the Glory of the Snow (*Chionodoxa luciliae*), and Blue-eyed Mary (*Omphalodes verna*); to yellow sheets of Daffodils, of *Saxifraga Haagii*, and of *Draba aizoides*; to the purples and reds of *Saxifraga oppositifolia*, Aubrietia, and *Primula rosea*; to the vivid green clusters of *Helleborus viridis*. Amongst the shrubs the Buffalo Currant (*Ribes aureum*) is emitting a clove-like scent from its yellow blossoms, while its relative the Fuchsia Gooseberry (*Ribes speciosa*) is perhaps suffering for its temerity; the white and yellow masses of Laurestinus and Forsythia make us feel that spring is truly here and pink blossom decks the Almond-trees above our heads.

Though the flowers of the early months of the year claim our interest because of the relative paucity of prevernal blossom,

the flowers of spring have perhaps an even greater claim on our affections. Our attention is not as yet dissipated in the diversity of interests which the summer brings, and the weather is clement enough to permit our enjoying the merits of the April flowers to an extent that is often denied to us during February and March. It is in April that we look forward to the Pheasant's-Eye Narcissi amongst the grass, reminiscent of the alpine pastures that are their native home; the blue stars of *Anemone apennina* recall the woodlands of Italy, and the scarlet of *Anemone fulgens* suggests the wastes of Palestine.

The shrubbery is now decked with the dainty inflorescences of the Japanese Cherries, and of the North American *Amelanchier canadensis*, with the fragrant blossom of *Viburnum Carlesii* from Corea, the white-rayed cups of *Magnolia stellata* from Japan, the scented clusters of *Osmanthus Delavayi* from Yunnan, the vivid scarlet of the Japanese Quince (*Cydonia japonica*), and the delicate yellow of the Chinese *Corylopsis*. The orchard is gay with the pink-cheeked blossoms of the Apple, the ivory white of the Pear clusters, the shining stars of the Plums, and the pendant bunches of the Cherry bloom. The woods and banks are yellow with Primroses, blue with the haze of the Wild Hyacinths, and white with the drifts of Wood Anemones.

We have mentioned only a few representative flowers of the respective seasons, but they suffice to show that the profusion of spring blossom at the gardener's disposal has been attained by the assemblage of plants from many regions. Often the spring-flowering species have been brought from climes more southern than our own where the chief flowering season is normally earlier. Many, for instance, come from the south of Europe, and still retain their normal flowering period despite the transference to a more northern latitude. Others are species which even in their own lands are characteristically early-blooming types.

Since flowers are for the plant a means to an end, and not, as for the gardener, an end in themselves, it is evident that the most suitable flowering season is that when pollination is most likely to be effected and the seed properly matured. Any tendency, then, to vary in the direction of earlier or later flower-

ing which does not fulfil these conditions would automatically disappear in the wild state, through a deficiency of offspring to carry on the tardy or precocious strain. Such considerations do not operate in the garden, where any seedlings are artificially protected and preserved, so that a less numerous progeny suffices to maintain the race, or where, if there be complete failure to set seed, we can use vegetative means of propagation to ensure continuity. So it is that we may find in gardens early- or late-flowering varieties which are not normally met with amongst the progeny of the same species in the wild state. The flowering period of the wild plant is often quite restricted, whereas that of its cultivated representatives may be very prolonged.

But we owe the panorama of the flowering season partly no doubt to the fact that though most of the insects that are effective as agents for pollination are met with in the summer-time, the choice of blossom at that season is so great that any one species may easily be neglected for others more attractive, either by reason of the quality or quantity of the nectar they secrete, or by reason of the ease with which it is obtained. There will, it is true, be far fewer insects to be attracted by the flowers that bloom in February and March, but in the comparative scarcity of food these insects will probably leave no flower unvisited, even though it might be entirely neglected were it to bloom in the abundance of summer. Hence the plants which flower at unusual seasons have been able to survive.

Particular flowers are adapted for pollination by particular insects—the Monkshood by the bumble-bee; *Yucca filamentosa* by a moth (*Pronuba*) which does not occur in this country, so that fertile seeds are not here produced. The relation in this instance is very remarkable, as the moth, in America, where the *Yucca* grows wild, emerges from its pupa at the precise flowering season and lays its eggs in the ovary. The moth then collects a mass of pollen from the *Yucca* stamens, and presses this into grooves in the stigma, so that pollination, and subsequent fertilisation, is effected. The caterpillars, which emerge from the eggs that were laid in the ovary, feed on a proportion of the young seeds which have developed as a consequence of fertilisa-

tion, whilst the surplus produces the plant's progeny. Pollination and fertilisation are thus as necessary for the continuation of the race of this moth as they are for that of the plant.

Elaborate pollination mechanisms are seen in many of our hothouse Orchids. In *Cypripediums*, for instance, which are usually visited by bees, the insect having entered a flower must escape by the far end of the 'slipper,' and in so doing passes successively by the single stamen and the stigma.

In most such specialised flowers the number of kinds of insects that can bring about pollination is small, or but a single species is effective, and unless the flowering season coincided with the time of the year when the appropriate insects were mature no fertile seed would be formed.

For those plants which depend on wind transference for their pollen there is no such seasonal restriction imposed by survival, and, indeed, we find that wind-pollinated flowers bloom more commonly in the early spring, or even in the winter, than in summer. The early-flowering period of the Elm, of *Garrya elliptica*, and of most catkin-bearing trees, all of which are wind pollinated, emphasises this point, whilst the numerous species of the exclusively wind-pollinated grasses and sedges flower at the most diverse seasons of the year, and even the main flowering season is much earlier than the maximum period for insect-visited flowers.

With the sequence of blossom that accompanies the changing year, we note also a sequence of colour. The yellows and whites preponderate in the spring, the reds and purples, and particularly the blues, becoming more frequent in the summer, with a return to the predominating yellows in the autumn. The infrequency of the blue flowers in the early part of the year is perhaps not unconnected with the fact that the bees which chiefly visit flowers of this colour do not become frequent pollinators until the year is well advanced.

Spring is the season of development, summer of flowering and fruition, but, as we have seen, there are many nonconformists to the prevailing mode, and no small insight can sometimes be gained into the needs of different species if we note

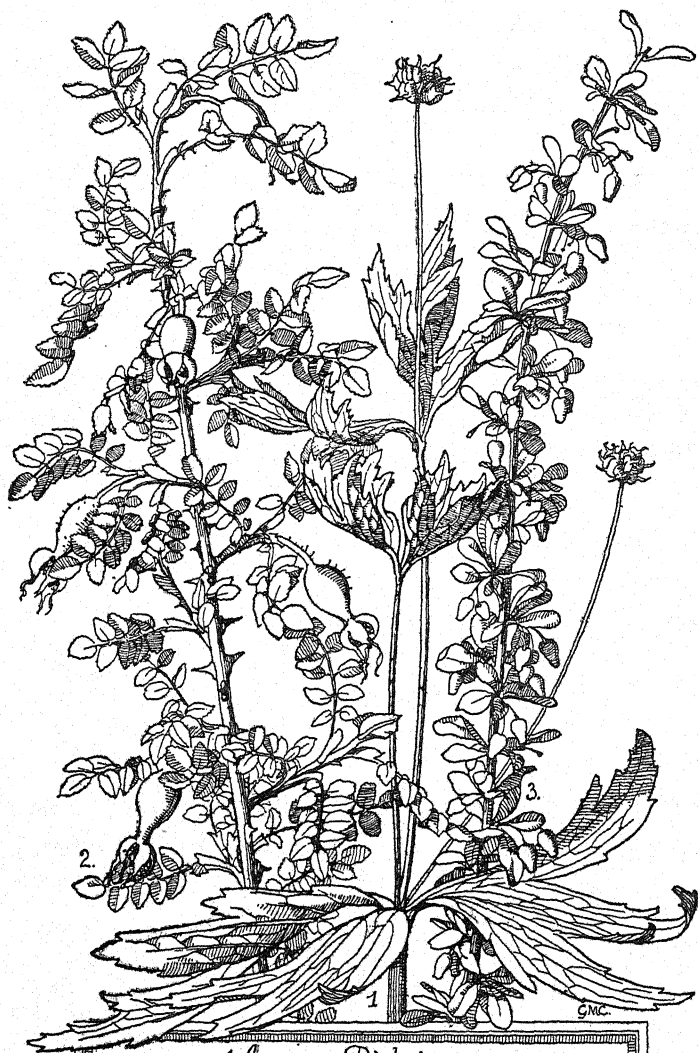
the times and seasons when they blossom, when they produce new leaves, and when they lose their old ones. The period of activity may be long, as in the evergreen, or short, as in the Winter Aconite, whose leaves, like those of many other woodland plants, wither at the period corresponding to that when the canopy of foliage would have formed on the shrubs and trees above it in its native woodland home. In general, the shorter the period of activity, the more the plant will suffer from any check to its growth.

The season of fruition and seed time is often regarded by us as the end, whereas for the plant it is but the prelude to a new beginning. Nevertheless there are not a few plants that we cultivate mainly for their ornamental fruits. It is rather remarkable how few horticultural enthusiasts have used, for ornamental purposes, the potentialities of the trees and shrubs that yield us edible fruits.

Few of our flowering trees or shrubs can vie in beauty with a Morello Cherry in full bloom, whilst in fruit it is almost as ornamental. So, too, many of the Apples and Pears, and a few varieties of Plum, not to mention Peaches and Medlars, are almost as ornamental in flower as in fruit.

But in all these, as with what are more usually termed ornamental trees and shrubs, more than half the beauty is lost if the natural form of growth is sacrificed in any degree to the lust of pruning. How successfully fruit production can be carried on even without any pruning whatever was demonstrated by the late Mr Spencer Pickering. If his methods were something of a counsel of perfection, we should none the less see to it that any necessary pruning is carried out so as to preserve the natural form of growth. The abortions produced by the Lorette system may be of considerable utilitarian value, but, like some ugly if efficient factory, have nothing to commend them but their productivity. The real test of good technique in the growth of deciduous trees and shrubs is that they should appear beautiful in winter when the dark framework we have coerced stands fully revealed.

Most of the ornamental fruits are in reality of the nature of



1 *Anemone Dichotoma*
2 *Rosa Moyseii*. 3 *Berberis Viridissima*.

baits, which induce birds and other animals to feed upon them and so to bring about dispersal of the contained seeds. One may wonder, therefore, is it mere coincidence that the majority of the fruits ripen just about the time when birds begin their restless movements preparatory to the autumn migrations?

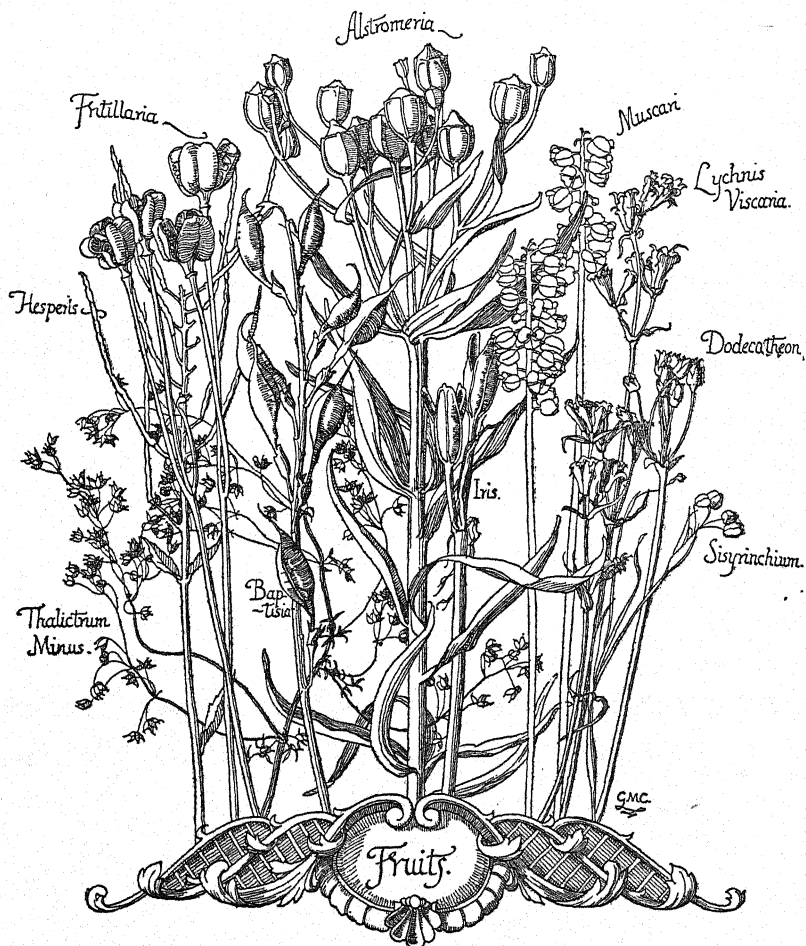
The majority of our ornamental fruits are red or orange in colour. The fruits of the Cotoneasters, of *Berberis vulgaris*, of *Rosa Moyesii*, *Sambucus racemosus* of the Aucuba, the Rowan, and the Holly are but a few familiar examples of trees and shrubs with red fruits, and amongst herbaceous perennials the fruits of the Lily-of-the-Valley and the Asparagus are red also. Raspberries, Strawberries, Red Currants share the same colour, and of these we also have the so-called 'white' varieties of which the fruits are in reality yellow. The wild strains of all three are usually red-fruited, and this is true of other wild species of which yellow-fruited types are known.

The fact that the yellow-fruited strains are rare, or do not occur wild, suggests that this colour may be less effective as an advertising sign, or else that its occurrence is associated with a lower vigour. The latter certainly appears to be true of the Raspberry, but it is also true that colour tests on birds suggest that in some species—perhaps in the majority—their vision is most responsive to red light. The Sea-Buckthorn (*Hippophae rhamnoides*) is one of the few shrubs with yellow fruits: white fruits are also rare, though the Snowberry is a familiar example.

Of black fruits there are, of course, many examples in our gardens—such as the Privet, the Baneberry (*Actaea*), *Viburnum lantana*, etc. Many of the blue fruits are rather blue-black or very dark purple, but possess a waxy bloom that gives the impression of blue. This is strikingly shewn by the fruit of the Flowering Currant, and the porcelain blue of the grapes of *Vitis heterophylla* owe their beauty to the same feature. The common Mahonia and Whortleberry (*Vaccinium*) afford other examples.

The dry fruits, such as those of the Cowslips, Snapdragons and Wallflowers, which begin to ripen in the summer season, mostly depend upon the wind for the scattering of their seeds.

So, also, the minute seeds of the Foxgloves and Verbascums become widely dispersed even by light breezes, whilst the much



larger seeds of *Nemesia* are readily carried away owing to the frill-like wing which each seed bears.

In the hot sun we hear the exploding fruits of the Everlasting Peas as the two halves of the pods suddenly split apart and twist up, throwing the seeds into the air, to be carried a short distance before falling by a sudden gust that may actually have caused the final rupture of the fruit. We watch the fruits of the Dandelions and Sow-Thistles being wafted on their silken parachutes from the weedy wastes into our garden and on to our flower borders. They perhaps remind us that it is time to collect the seeds from our flowers before they too are scattered, and, as we pass from one plant to another, we cannot but be struck by the variety of the capsules in which the seeds are contained, and the great diversity of the seeds themselves.

After fertilisation not only the ovules but the ovary also usually undergoes marked changes as it develops into the 'fruit.' But these changes may exceptionally involve other parts of the flower, producing a structure which though not technically a fruit is popularly designated such. In the Strawberry, for example, the actual fruits are the dry pips, but the succulent flesh is due to swelling of the end of the flower-stalk on which the fruits were borne: the fruit of a garden *Potentilla* is precisely similar except for the absence of any swelling of this part of the flower. In the Mulberry the so-called 'fruit' represents an entire inflorescence, as is also the case in a Fig or a Pineapple. The true fruit of the Apple is only the core, the part we eat being the stalk in which the core is embedded. All of which examples serve to show that the stimulus which leads to the production of embryos within the seeds may produce striking alterations in surrounding tissues.

The nature of the fruit is often to a marked extent associated with the family to which the plant belongs, but the method by which the seeds are dispersed is often a feature unique to the particular kind of plant. Though much is known respecting the structure of fruits and seeds, and their mechanisms of dispersal, we know all too little respecting the actual distances to which the seeds are carried in natural conditions, and this is a field of enquiry in which the owner of a garden might obtain useful data.

With the approach of winter our attention passes from the ripening fruits to the changing foliage. The glory of the autumn, though the symptom of approaching death, paints the shrubs and trees with glowing tints like the sunset colouring of the departing day.

The clear yellows of the Tulip-tree, the Maidenhair-tree, and the Birches are witnesses to the disintegration of the green pigments whose decomposition products are conveyed away, leaving behind the yellow xanthophylls.

The vivid reds of *Quercus coccinea*, *Euonymus alatus*, *Rhus typhina*, *Sorbus torminalis*, and many others, are a consequence of the development of anthocyanins, which are a usual accompaniment of excessive accumulation of sugars in the leaf. Even in summer the semblance of autumnal coloration may result from such accumulation, owing to the rapidity of food manufacture exceeding the rate of its removal and utilisation. This condition may be brought about in various ways, of which the most frequent are probably deficient water-supply or nitrogen starvation. Red-leaved varieties of ornamental Maples, purple-leaved *Rhus cotinus*, and Red Orache (*Atriplex hortensis*), in common with other plants that are grown chiefly for their colour effects, due to the anthocyanin which their leaves normally develop, all tend to have more intense coloration in a dry summer, whilst too rich feeding with nitrogenous manures is apt to have a pronounced effect in the reverse direction. In the autumn, accumulation of sugars and accompanying coloration is probably mainly the consequence of the continued food formation at a period when the removal of these sugars becomes increasingly sluggish and they are not being utilised for growth.

Thus sunny days followed by cold nights are most favourable to intense coloration, since the former promote the manufacture of the sugars, whilst the latter check alike their removal and the absorption of nitrates that might promote their utilisation.

Because disintegration of the chlorophyll by sunlight is essential for the development of the most brilliant colours, trees and shrubs yield much better tints when grown in full sunlight than when partially shaded. So, too, the south side of a tree

develops better coloration than the north side; and the change is hastened and intensified by drought.

The alterations with the seasons are, however, not the only types of change that the observant gardener will note. There is also the continuous manifestation of life throughout the twenty-four hours, involving a daily rhythm in the activities of the plants, and frequently accompanied by visible changes in the external appearance of the foliage and flowers.

The daily rhythm is often associated with the variations of light intensity, of temperature, and of humidity of the air, as day succeeds night and night succeeds day; and by the effects of these on the plants around us we are constantly reminded that they are living organisms with the capacity of forming habits and performing movements analogous to those that we associate exclusively with the animal kingdom. By these and many other features we apprehend that though plants are essentially sedentary organisms, and as such do not stand in need of the highly developed sensory perception which mobile animals exhibit, yet, in so far as it is essential to their welfare, plants show a perception of changes in the surrounding conditions—such as light, humidity, and gravitational stimulus—that is far greater than our own. They manifest this sensitivity usually by curvatures of growth, the direction of which bear a definite relation to the intensity, and often also the direction, of the stimulating cause.

In the evening we find that the appearance of the leaves of the *Oxalis* in our rock garden, or the Wood Sorrel in the spinney, has altered. The leaflets have closed together by a downward movement. So, too, the leaflets of the False Acacia (*Robinia*) have drooped downwards in pairs, whilst those of *Acacia lophantha* have undergone a similar change, though in this tree the leaflets have folded upwards into the night position, just as we shall find is the condition of the Clover leaves upon our lawn.

If we wander round our garden of a spring evening, about eight o'clock, we shall find that the *Anemones*, whether it be

the scarlet flower of *Anemone fulgens*, the vivid blue of *A. apennina*, or the pink of *A. stellata*, have all closed up their flowers. If we extend our walk into the woodlands, the brilliant yellow of the lesser Celandine and the shining white of the Wood Anemones will no longer be seen, as the flowers will all have closed up, presenting to us the duller tints of their outer surfaces. The flowers of the Crocus have closed also, and so, too, have those of the Winter Aconite.

The following morning, if it be a sunny day, we shall find that the drooping heads of the Anemones have become erect, and the flowers have spread wide open. This usually takes place between eight and nine o'clock in the morning, and the flowers normally close between five and six in the evening. The warmer the day the earlier the flowers open and the later they close. If the day is cold and cloudy the Anemones may remain shut all day. If, however, we gather some flowers of *Anemone apennina*, and bring them into a warm room, they will soon open, and even though we put them into a dark cupboard they will remain open, provided they are kept warm, throughout the twenty-four hours.

It is evident, then, that the opening and the closing of Anemones are mainly responses to changes in temperature, and this is true also of the Celandines, Crocus, Winter Aconites, the Spring Adonis, and the Autumn Colchicum.

The rapid opening of Tulip flowers when we bring them into a warm room is a familiar experience that bears witness to the sensitiveness of these flowers to a sudden rise in temperature. Indeed if the temperature be reasonably warm a rise of 1° – 3° C. (ca. 2° – 5° F.) is sufficient to cause this opening. Crocus flowers are even more sensitive. Some species will respond to a rise of half a degree, and *Crocus vernus*, the most sensitive of all those studied, opens with a rise of only one-fifth of a degree.

It follows that the warming effects of the gleams of spring sunshine are sufficient to induce the Crocus to spread open its flowers, and the less sensitive character of the Tulip involves no disadvantage, since it blooms later in the season when the higher altitude of the sun provides greater warmth. The cooler the air, provided it be already sufficiently warm, the more sensitive the

flower is to the rise in temperature. In the Crocus, the minimum temperature at which the flower will respond to an increase of warmth is about 8° C. (44.4° F.). As the flower ages, it usually becomes less sensitive to the external changes.

The opening of the flower-heads of the Star of the Veldt (*Dimorphotheca*), or of that other beautiful South African Composite, *Arctotis*, is also mainly influenced by temperature changes, but here light intensity has an appreciable regulatory effect as well, though not, apparently, change of humidity. The recent experiments of G. W. Goldsmith and A. L. Hafenrichter, in America, on these two plants, show that under constant conditions of temperature and humidity opening and closing of the heads will take place, though not with such regularity, in continuous darkness; showing a certain innate rhythm influenced, however, by the previous treatment to which the inflorescences have been subjected. The opening of the flowers of *Eschscholzia*, of the Red Flax (*Linum*), of *Portulaca*, or of *Hibiscus*, is likewise mainly influenced by increasing warmth, and their closure by cooling. The association, in many of these spring and summer flowers, of opening with a rise in temperature and closure with a fall in temperature, automatically confers a measure of protection both to the pollen and the nectar against the effects of rain (since the dark clouds will have caused a sufficient drop in temperature to bring about closure) and also, perhaps, protection against excessive radiation at night.

Later in the season the blue flowers of the Gentians show similar 'sleep' movements, due mainly to the daily changes of temperature. That difficult species of the rock garden, *Gentiana ciliata*, responds, it is true, to changes of illumination, but most of the species of this genus open their flowers with a rise of temperature and close them when the temperature falls. Here, too, the opening will not take place unless the air is sufficiently warm, and the minimum temperature required varies according to the species concerned. The familiar *Gentianella* (*Gentiana acaulis*) will respond to a rise of temperature only if the air is above 8.5° C. (ca. 47° F.). For the Spring Gentian (*Gentiana*

verna) the air needs to be slightly warmer, about 10° C. (50° F.), whereas the June-flowering *Gentiana cruciata* will only open its flowers when the temperature of the air has reached about 20° C. (68° F.). So naturally the time at which these flowers open will depend on the warmth of the day, and usually the Spring Gentian will appear to 'wake' later than the *Gentianella*, whilst *G. cruciata*, if it flowered at the same season, would open its flowers later in the day than either. The age of the blooms, the time of day, and the conditions of growth, all affect the readiness with which the Gentian flowers open.

In this group of plants the mechanism depends upon changes in the turgor (*i.e.* degree of distension through intake of water) of the cells forming that part of the corolla where the petals join the tube. Nevertheless there is no response to changes in humidity as such. The flowers close rapidly when shaken, and, in nature, the same stimulus is produced by the impact of rain-drops upon the flowers. On a warm day the flowers of *Gentiana verna* will close within about a minute after drops of rain fall on them, and that this is not merely another example of the effect of a fall in temperature can be seen if we sprinkle the flowers with warm water, when the closure takes place just the same.

The flower-heads of most members of the Dandelion family (Compositae) show similar so-called 'sleep movements,' normally closing at night and opening in the daytime. The Daisy, or Eye-of-day, owes its name to this behaviour. If we cover over a patch of Daisy- or Dandelion-heads with an inverted box, we shall find that they do not open or close at the same time as those which are uncovered, showing us that light has something to do with the movement, and if we place Dandelion-heads in a vase of water in a warm room they will remain open in the dark long after others out of doors have closed. So that both light and temperature are involved in these movements. The flower-heads of these plants, and of the common garden Marigold (*Calendula*), continue to open and close in darkness, but the normal daily changes in temperature and illumination have a regulatory influence upon these movements.

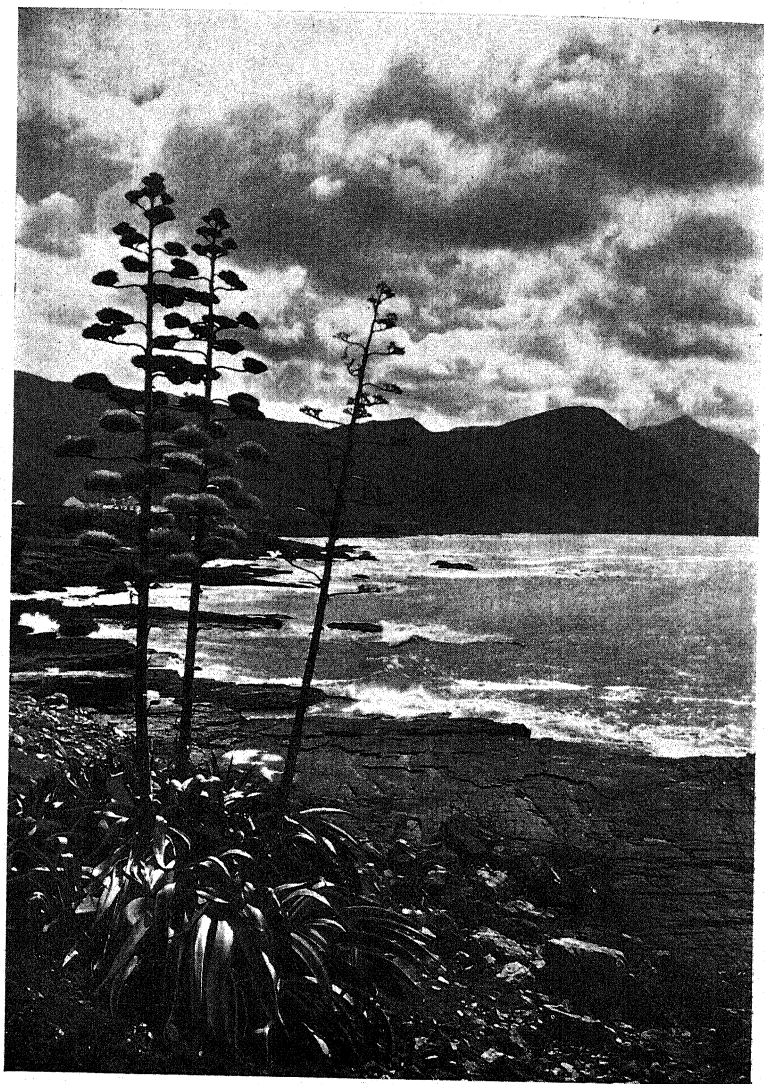
The story of the Sunflower that turned its head with the

PLATE XI



NIGHT AND DAY APPEARANCE OF THE FLOWERS OF
Anemone apennina

Note how the flowers close and bend over at night [x $\frac{1}{2}$]



THE CENTURY PLANT OF MEXICO (Agave)

By permission of the High Commissioner for the Union of South Africa

movement of the sun and eventually twisted itself off the stalk, like most such stories embodies a partial truth that has been caricatured. The Sunflower affords a good example of a daily movement influenced by light. The actual sequence of events alike in the Sunflower and a number of other members of the Compositae is that the flower-head turns with the direction of the sun's rays, but, after the sun has set, the flower-head becomes erect, and before sunrise has again bent over towards the east. The whole movement is probably an accompaniment of irregular growth, which tends always to be greatest on the shaded side: hence the flower-head always bends towards the light. After dark the illuminated side, on which growth during the day was slower, catches up, and the stalk straightens. Indeed it rather more than catches up, because the growth in darkness, and the humid air of night, is more extensive than that on the shaded side in the drier air of day. So the stalk becomes bent over, eastwards, to continue its nodding orbit the succeeding day.

The flowers of some species of *Silene* which are pollinated by night-flying moths, such as *Silene noctiflora*, close in the daytime and open at night, a change that is conditioned by the rise in humidity of the air in the evening and its decrease in the daytime. In *Silene saxifraga* the opening of the flowers at night has not only been shown to be due to the rise in humidity, but to be independent of either light changes or changes in temperature. But the night-flowering *Mirabilis jalapa*, which opens its flowers about five o'clock in the evening, is mainly influenced by temperature, and only slightly by humidity and light.

The difference in behaviour of the White Water-Lily and the *Victoria regia* is interesting, since the flowers of these closely related plants behave in the opposite manner; those of the former close at night, whilst those of the latter close during daylight. So, too, the species of *Silene* which are visited by day-flying insects behave in the reverse sense to those, just described, visited by moths.

The individuality of plants as regards their daily movements is perhaps best shown by the Salsify (*Tragopogon*). Its flower-

heads open in the morning and close at mid-day, hence the popular name of 'John-go-to-bed-at-noon' which the wild species of this genus bears. The 'Poor-man's-weather-glass,' or Scarlet Pimpernel (*Anagallis*), is a flower which responds to temperature and humidity changes, but the flowers normally close, whether it be wet or fine, at about 3 p.m. These closures during the daytime are probably to be attributed to a reversal effect which takes place when a definite interval of time has elapsed since the flower opened.

The daily movements of the leaflets of *Acacia lophantha* and of the flowers of *Oxalis* continue for some days if kept constantly darkened or constantly illuminated. The leaflets of the Scarlet Runner if looked at during the day are seen to be more or less horizontally spread, but they droop downwards at night. This movement takes place in response to the changes in illumination, but continues for some days if the plant is kept in darkness. It is possible, however, by keeping the plant in darkness during the daytime and subjecting it to artificial illumination at night to build up a new rhythm, after which, if returned to the normal conditions, some days must elapse for the old habit to be again acquired. Even in the seed-beds we find that there are changes from day to night, the seed leaves of the Sunflower and *Mimulus*, or of the Melon, which spread apart by day, come together at night like the closing of a book.

It is evident, then, that the daily changes we observe in our gardens accompanying the alterations from day to night may be associated with any one, usually more than one, of the changing conditions. Some as we see respond mainly to changes of temperature, some to changes of light, some to changes of humidity, modified or not, by one another. But the exact nature of the response is clearly related to the mode of life of the plant concerned. Furthermore, we have here clear evidence that plants form habits that persist for a time under changed conditions.

This periodical opening and closing of flowers naturally struck the earlier gardeners, and gave rise to the conceit of constructing beds in which the form was that of a clock-face divided into a

number of segments each occupied by a species which opened or closed at a particular time of the day. It need hardly be emphasised, having regard to what has already been stated as to the several conditions that determine these movements, that such 'floral clocks' or flower dials were sometimes 'fast,' sometimes 'slow,' and inevitably erratic in their functioning. Loudon in his *Encyclopedia of Gardening*, published in 1822, gives a list of plants for such a 'dial,' which is reproduced here because of its interest, and not because of the accuracy of the stated times, despite the fact that these are given to within a few minutes. Still the list illustrates the variety of plants, which show such 'sleep movements,' and also the considerable differences as to the periods of the day at which the flowers open or close.

DIAL PLANTS

(from J. C. Loudon, 1822)

Species	Opens in the morning at		Shut from noon to night	
	Hours	Mins.	Hours	Mins.
Tragopogon luteum	3	5	9	10
Leontodon serotinum	4	0	12	1
Picris echioides	4	5	12	0
Crepis alpina	4	5	12	0
Cichorium intybus	4	5	8	9
Papaver nudicaule	5	0	7	0
Hemerocallis fulva	5	0	7	8
Sonchus laevis	5	0	11	12
Sonchus alpinus	5	0	12	0
Convolvulus arvensis	5	6	4	5
Lapsana communis	5	6	10	0
Leontodon Taraxacum	5	6	8	9
Hypochaeris maculata	6	7	4	5
Nymphaea alba	7	0	5	0
Lactuca sativa	7	0	10	0
Tagetes erecta	7	0	3	4
Anagallis arvensis	7	8	2	3
Hieracium pilosella	8	0	2	0
Dianthus prolifer	8	0	1	0
Calendula arvensis	9	0	3	0
Arenaria purpurea	9	10	2	3
Portulaca hortensis	9	10	11	12
Malva caroliniana	9	10	12	1
Stellaria media	9	10	9	10

The work of the American investigators, already referred to, in which a number of different kinds of flowers were observed under carefully controlled conditions of humidity, temperature,

and light, indicates that the majority show an innate periodicity of behaviour which is regulated, sometimes very markedly, sometimes only slightly, by the changes of temperature, light, and moisture in their surroundings. The following average times given by Goldsmith and Hafenrichter may be taken as a much closer approach to what we shall find in our own gardens than the amusingly precious figures of Loudon. But the facts stated above show us that the idea of a floral clock, charming though it is in theory, in practice fails because of the wide range of time for opening or closing according to the conditions which affect the different flowers in differing degrees.

	Opens about	Closes about
<i>Anagallis arvensis</i>	8 a.m.	2 to 3 p.m.
<i>Anagallis grandiflora</i>	8 a.m.	3 to 4 p.m.
<i>Arctotis grandis</i>	7 to 9 a.m.	6 p.m.
<i>Cichorium intybus</i>	7 a.m.	
<i>Convolvulus sepium</i>	5 a.m.	1 p.m.
<i>Dimorphotheca aurantiaca</i>	6 to 7 a.m.	Early afternoon
<i>Eschscholzia californica</i>	7 to 9 a.m.	6 p.m.
<i>Gilia densiflora</i>	7 a.m.	4 to 5 p.m.
<i>Hibiscus trionum</i>	Before 6 a.m.	10 a.m. to mid-day
<i>Ipomoea purpurea</i>	4 a.m.	10 a.m.
<i>Linum rubrum</i>	6 to 7 a.m.	12 to 4 p.m.
<i>Mirabilis jalapa</i>	5 p.m.	withers early morning
<i>Portulaca</i>	10 a.m.	5 p.m.
<i>Oenothera</i> spp.	6 p.m.	withers in morning
<i>Tragopogon</i> spp.	10 a.m.	11 a.m.

There is still a great deal to learn about these periodic movements of plants, and careful observations in the garden could probably do much towards a better appreciation of their significance.

The majority of the plants so far experimented with show evidence of a rhythm analogous to what, in animals, we should term habit; this is apparently to some extent independent of external conditions, but modified by the present and previous state of the plants' surroundings.

But whether it be the rhythm of the plants' growth with the changing year, or the periodic daily sequence in the flower or leaf, we are alike witnessing manifestations of the behaviour of plants as living organisms in which the changes we observe,

though partly regulated in their occurrence by external conditions, are in the form of their expression directly connected with the demands which the mode of life of the plant necessitates; and to these needs are also related the particular stimuli to which the plant responds.

CHAPTER XV

ON CUTTING LAWNS AND HEDGES

'Nothing is more pleasant to the eye than green grass kept finely shorn.'

BACON. ESSAY 'OF GARDENS'

A WELL-TRIMMED LAWN, a cricket pitch, or a golf green, are all so pleasing to the eye, yet so sophisticated in appearance, that we are almost apt to forget that this velvety sward is produced by repeated mutilation of the long-suffering grass, which endures this treatment in a manner that would appeal to us as remarkable if it were not so familiar a phenomenon. Let us pause for a moment to consider what are the actual effects of the very unnatural conditions to which we subject the plants—mostly grasses—which constitute our lawns.

First of all, what are we really doing? By means of a mowing machine we remove a considerable part of the leaves of these plants once or twice a week throughout the growing season. When we gaze at the heaps of grass cuttings that result, we probably seldom, if ever, stop to think of what this material consists, and whence it comes. Actually, of the total weight of the fresh grass cuttings, about eighty-five out of every hundred pounds is water, which the plants have taken up from the soil. We might, indeed, have expected a large proportion of fresh grass to consist of water from the fact that in a dry spell the grass requires cutting much less frequently than in wet weather. The quantity of water is actually rather less than in many other green leaves, which frequently contain about ninety per cent of water. This proportion is naturally lower in dry weather and higher when the air is moist; so that leaves near the ground, protected from the wind, and therefore in moister air, usually contain more water than those higher up on the stem, which are more exposed.

Owing to the continual cutting, all the leaves in the lawn are

close to the soil, but, despite the mutual shelter from the wind, they contain appreciably less water on a sunny day than when the air is damp. If we evaporate all the contained water away, there remains about fifteen per cent of dry residue, and if we had collected together all our grass cuttings throughout the growing season and dried them, we should probably find that the total weight of dried grass from an acre of lawn would be somewhere about five thousand pounds, or rather more than a pound per square yard. Now, this dry matter, though consisting in greater part of organic material, built up by the plant from water and carbon-dioxide, also contains an appreciable quantity of mineral substances derived directly from the soil.

The living matter of the plant partly consists of substances containing nitrogen, which element is absorbed from the soil through the root, mostly in the form of nitrates. From every hundred square yards of lawn some three pounds of nitrogen are removed each year in the grass cuttings. Since we take the grass cuttings away, there is no chance of the substances which they contain returning to the soil, though such a return occurs to some extent in grasslands which are neither grazed nor mown—since they again become available in the process of decay.

But although this nitrogen is permanently removed, the supply of nitrates in the soil is continually replenished through the activity of certain bacteria, some of which live freely in the soil and others in the swellings which we see on the roots of clovers and vetches. These bacteria are microscopic plants which possess the capacity for combining the free nitrogen of the air to form nitrates, but they are usually most active in soils which are not acid and which contain lime.

Despite the presence of these bacteria in our lawns, the grass often shows a marked improvement if we add manures such as ammonium sulphate or nitrate of soda, either of which contain nitrogen in a form that the grass can absorb. The resulting improvement is a visible sign of the existence of a nitrogen deficiency. But in addition to the nitrogen that we have removed from our hundred square yards of grass, the grass cuttings would also contain about one and a half pounds of

lime and about a pound of phosphoric acid, both of which are essentials for plant growth.

Over and above the lime removed in our cuttings, lime is also being gradually dissolved away from the soil by the rainwater which falls upon and percolates through it. Moreover, if we have added ammonium sulphate to improve the nitrogen supply in the soil, then, owing to the chemical changes which this brings about, the lime in the soil will be leached out by the rainfall approximately twice as fast as before this artificial manure was added. There are no natural recuperative agents to replenish either this lime supply or the phosphoric acid, except that if earthworms are present they will somewhat delay the effect of leaching by bringing unleached soil from below, and depositing it on the surface in their wormcasts. This remedial influence of earthworms is, however, generally regarded by the gardener as worse than the evil which it tends to cure.

The result of our continual cutting as the years go on is, then, to impoverish the soil more and more of essential food-supplies, and also usually to bring about an acid condition. The effects of this result are not as undesirable as we might anticipate, since, in general, the finer-leaved grasses, which we prefer to the coarser sorts, in our lawns, are far more tolerant of such impoverished conditions and so tend to increase. If, however, the process brings about too extreme an acidity, bare patches may develop and thus do not become again clothed with grass unless we apply remedial measures such as liming (to check the acidity and cure the lime deficiency) and potassic and phosphoric manures (to supply the shortage in these requirements).

But long before changes of this character appear we shall have noticed the tendency for plants with flat rosettes of leaves, such as Plantains and Daisies, Cat's Ear and Dandelions, to increase in size and multiply rapidly at the expense of the grass which we desire to preserve, unless we have continually uprooted the intruders by hand or destroyed them by the use of lawn sand. If part of a piece of rough grass is continually mown to convert it into a lawn, the rapid increase in such weeds as those just mentioned will soon become only too evident. On the other

hand, the comparable pasture that has not been mown will usually show no tendency for these plants to increase. In an experiment of this character carried out by the author, where the weeds were permitted to increase without removal, there were, after three years, about sixty rosette plants to the square yard in the grass that had been regularly cut, whereas on the uncut area the number had remained constant at about five to the square yard. This difference is mainly due to the fact that, when uncut, the grasses are able to compete successfully with these weeds because of their greater growth in height, whereas repeated cutting takes away this advantage, so that the leaves of the rosette plants, which are mostly untouched by the lawn-mower, remain unshaded, and indeed themselves spread over the grass and kill it by cutting off the essential light rays.

If a rosette of a Cat's Ear or Plantain be carefully taken up and held by the tap root, it will be seen that the leaves at once begin to curve downwards, thus showing that the leaves would be actually pressing down on to the soil or any underlying vegetation. This is due to greater growth of the upper as compared with the under side of the leaf-stalks. But this unequal growth on the two surfaces of the leaf is only produced when the plants are growing in bright light. When shaded by surrounding vegetation, it will be noticed that the leaves of the Plantains, etc., are no longer spread out flat upon the grass, but turn obliquely upwards, and so do not materially diminish the light which reaches the leaves of their neighbours. The lawn is indeed a community of plants in which the competition for light and space and essential foods is somewhat severe, but the usual relations as regards relative heights of the species are upset by the artificial pruning to which the grasses in particular are regularly subjected.

It is noteworthy that the weeds of lawns are nearly always perennials, with rosettes of leaves which, themselves almost unharmed, be the lawn-mower never so closely set, benefit from the repeated checks to their rivals' growth. Usually in wild communities of plants which form a continuous carpet of vegetation annuals have little chance of success, since the

seedlings would of necessity have to germinate beneath the shade of the existing occupants; but in the close-cut lawn even annual weeds can sometimes find a place, if they are of sufficiently low growth. Hence the annual Pearlwort and the Lesser Hop Trefoil are not infrequently to be found amongst the grass where the turf is not dense.

It is the small bare patches which give the annuals their chance of establishment, and in this connection we may note that grass varieties vary in respect to their capacity to form lateral shoots, or 'tillers.' Those varieties of Red Fescue, for instance, which tiller abundantly, are the most suitable for lawns or golf greens, because they form a dense turf which covers the ground more efficiently, and so tend both to suppress weeds and to prevent their establishment from seed.

It is the rather poor cover to the soil which a close-cut lawn affords that is mainly responsible for another effect, due to rainfall. We are all familiar with the way in which the impact of the raindrops on bare earth gradually packs tight the surface crust, as an outcome of which the aeration of the soil is hindered. This is true also of many lawns where the turf is rather sparse. As a consequence of rainfall the roots of the grass suffer from lack of air and we have recourse to the spiked roller to break up the crust which has been formed at the surface.

If we ceased to cut our lawn for a few years we should find that the tall growth of the herbage was accompanied by a marked decrease, and even disappearance, of most of the rosette plants, whilst tall-growing perennials would soon make their appearance, followed by shrubs, and eventually trees; so that our lawn would pass from grassland to thicket, and eventually to woodland. A similar repression of taller plants is to be observed on well-grazed pastures, where the browsing sheep and nibbling rabbits perform the function of the mower and debar the downland pasture from becoming woodland—as it actually does where effective enclosure prevents the access of all browsing animals.

In pastures, only a small proportion of the materials removed by the grazing animals is returned, in their droppings, to the

soil, by far the greater part being contained in their bodies. So that in heavily stocked pastures there is a similar impoverishment of the soil to that brought about by repeated mowing and removal of grass cuttings. Such impoverishment has caused serious deterioration of pastures in New Zealand and elsewhere, sometimes accompanied by such a decrease in the plant covering that the soil has become eroded away by rainwash. Such examples serve to show that the removal of nutrient substances from the soil is not a negligible matter, but may produce changes of considerable magnitude.

A word may be added respecting the comparable treatment of hedges which are constantly clipped. Here we are not so much concerned with competition, although it may be mentioned that the infrequency with which seedlings of other species grow up within the hedge is almost entirely dependent upon the continuous character of the leaf canopy which we maintain by clipping.

The continual cutting and removal of the hedge clippings involves, as with the lawn, a continual drain upon the soil, so that even hedges may require manurial treatment to restore their vigour.

Hedges may cause suppression of neighbouring plants by their shade, but more frequently any harmful effects they may produce in their immediate neighbourhood are due rather to competition for water, so that the extent of the root systems of the hedge plants is of some importance as affecting plants grown near them.

Experiments seem to indicate that repeated cutting of either grass or shrubs tends to check the root development. Hence, to diminish the competitive influence of shrubs for water as far as possible, it would appear that continuous trimming is more likely to be effective than if appreciable growth is permitted between the intervals of cutting. If vigorous shoot growth be permitted at any time unchecked, there will be corresponding development in the root system. When the shoots are subsequently cut back the plant will have an extent of root larger in proportion to the size of the shoot system, and the latter will,

therefore, tend to grow more rapidly than if it had been constantly kept in check. The converse is also true, and sometimes a hedge which lacks vigour can be encouraged in its growth by deliberately permitting a longer period of growth before cutting back. It should be remembered, too, that the more even the trimming the more completely will the shoots and leaves of the plant afford protection to one another from the drying action of the wind, so that a badly trimmed hedge probably makes appreciably greater demands upon the water-supply of the soil than one which is kept well cut.

Since our trimming, whether of hedge or lawn, removes a considerable part of the plant's foliage, it is evident that we greatly reduce its capacity for making food. It is, therefore, better to trim our lawns frequently with a rather high-set mower than to cut them very close at longer intervals. This not only gives the grass a better chance of growth, but maintains a more complete cover, with the consequent benefits already referred to.

In pruning our hedges or mowing our lawns, we are, therefore, carrying out a long-continued experiment in competition that has many unforeseen consequences. The realisation of this will often enable us not only to keep our garden in better order, but to foster added interest in the processes we have deflected from their normal course.

CHAPTER XVI

PLANT NAMES

'Words are wise men's counters: they do but reckon by them, but they are the money of fools.'

HOBBS. THE LEVIATHAN

THE English names of garden plants sometimes afford an interesting clue to the folk-lore of the past; sometimes they express outstanding qualities, not infrequently they are fanciful inventions, and occasionally they serve merely to perpetuate errors.

The inappropriateness of many popular names of garden plants is in striking contrast to the aptness of those of some of our wild flowers, such as Lady's Mantle which refers to the folding of the leaves like a mantle of Tudor days: the name Town Hall Clock for *Adoxa moschatellina*, with its cube-shaped inflorescence of five flowers, four of which face in different directions like miniature clock faces: or the name Fairy Larch by which *Equisetum sylvaticum* is known in parts of the north, and Jack-in-the-Pulpit for *Arum maculatum*—names that are as apt as they are picturesque.

The English designations of most garden plants fall far short of these country names of wild flowers in their vivid characterisation, but there are a few exceptions. What could be more appropriate than Pin-Cushion Flower for the common garden Scabious? The flower-head of this plant, with the projecting stamens seen in profile, suggests irresistibly a pin-cushion stuck with pins. The soft hairy leaves of the Caucasian *Stachys lanata* render the names Lamb's Ear and Donkey's Ear peculiarly apt; even Bouncing Bet for the double variety of *Saponaria officinalis*, with its suggestion of the 'naughty 'nineties,' has a certain poetic quality.

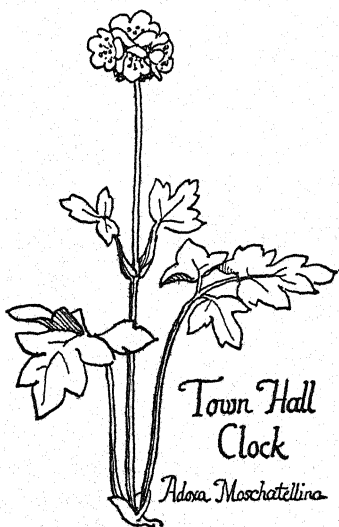
Tribute to the plant-lore of the past is furnished by the name Burning Bush for *Dictamnus fraxinella*. On a hot, still day, and in a sheltered spot, the volatile oil given off by this plant

collects in sufficient quantity to render inflammable the air around it. If a lighted match be held near the plant, the gaseous mixture ignites with a mild explosion and a visible flash of flame. But these are exceptions, for most of our English names of garden plants are prosaic inventions or mere translations of the Latin binomials.

No better instance of the accurate observation often enshrined in popular names of wild plants could be furnished than that of Devil's Bit (*Scabiosa succisa* L.). The root of this plant was formerly in very great repute for its supposed medicinal virtues. Its name is associated with the old superstition that the Devil, annoyed that the plant did so much good in the world, bit off the root from every plant. The roots were collected by the herbalists from the wet meadows where the Devil's Bit abounds, and, if we dig up a plant from such a situation, we commonly find that the tap-root presents the appearance of having been roughly bitten off short, whilst a number of side roots have grown obliquely outwards from the stump. Actually in drier

well-aerated soil the tap-root may persist, but in water-logged ground it commonly rots away and side roots develop in the better aerated layer near the surface. The name is therefore not merely a testimony to the poetic fancy of our forefathers, but to the closeness of their observation.

It is significant that the garden flowers that have Saxon names are mostly those of wild species that have been taken into cultivation—as, for instance, Woodruffe and Cowslip. Gardens, in the sense that we know them to-day, where plants are grown as much for ornament as for use, are of comparatively recent origin, the



separation of the flower garden from the herb garden dating back to about Tudor times. Prior to that period the herb garden took precedence of the cult of flowers, and we owe the early knowledge of herbs in large measure to their monastic cultivators. It is scarcely surprising, therefore, to find many names of Latin origin amongst the flowers grown in early times. The Rose, the Lavender, the Lily, and the Columbine, all of which were already to be found in gardens of the sixteenth century, bear names little altered from their Latin designations. The name Crocus is of Greek origin, whilst even the English-sounding name of Daffodil is but a corruption of *Asphodelus*, a name we now apply to a totally different genus.

The common names of some plants serve to indicate the country from which they were first brought—as, for instance, Lilac, which is but a slightly altered version of the Persian word for a flower. Candytuft, that we might reasonably suppose referred to the white clumps of this plant when in bloom, is in reality derived from Candia, the ancient name of Crete, whence the plant was first introduced. Early American introductions are embodied in the names Virginia Creeper and Virginia Allspice. But such regional appellations may be more misleading than a peer's title. The Virginia Stock (*Malcomia maritima*) comes not from America, but from the south of Europe. The French Mulberry (*Callicarpa americana*) is neither a Mulberry nor a native of France; in fact it derives from the southern states of America, and is a member of the Verbenaceae family, not of the Moraceae, to which the Mulberry belongs. French Marigolds (*Tagetes*) hail not from the Mediterranean region, but from Mexico, whilst the Greek Mallow (*Kerria*) is a native of Japan. The Guernsey Lily (*Nerine sarniensis*) is not, as we might suppose, a native of the Channel Islands, but like the so-called 'Scarborough Lily' comes from Cape Colony, and belongs to a genus peculiar to that region. Even the familiar London Pride (*Saxifraga umbrosa*) has but an indirect relation to the Metropolis; it is a native of the Pyrenees, Spain, Portugal, and Ireland, and was introduced into cultivation by a firm whose senior partner was a Mr. London.



PLANT OF DEVIL'S BIT SCABIOUS
Drawn to scale by the author showing the abbreviated tap-root. ($\times \frac{1}{4}$.)

Some English names are clearly the result of mispronunciation and subsequent rationalisation into a normal form. An amusing example is the gardener's corruption of the Latin name *Leycesteria* into Elisha's Tears, which it approximates in sound, just as the famous onion Ailsa Craig is sometimes heard of as Elsie Craig. The Jerusalem Artichoke has no connection whatever with the Holy Land, although the chef, under this misapprehension, makes 'Palestine soup' from its tubers; it is a North American plant, which was introduced into Europe in 1617, and is said to have been distributed from the Farnese gardens at Rome under the name *Girasole Articcocco*, or Sun-turning Artichoke, and this became corrupted into Jerusalem Artichoke. The gardener's name of Laurestinus for a plant that is really a Viburnum (*Viburnum Tinus*) is as misleading as the name Laurel for a shrub that is actually a kind of Cherry. Cotton Lavender is not related to the true Lavenders, but is more nearly allied to the Daisy.

The confusion of common names is sometimes even greater—as, for instance, the use of *Syringa* for the Mock Orange (*Philadelphus*) when *Syringa* is correctly the generic name of the Lilacs. An example of a misleading invention is the name Strawberry-Raspberry, which carries the conception of mongrel origin, for a species of Blackberry of unblemished parentage. So, too, the name Cornelian Cherry for a tree which is not even remotely related to the edible variety, but is a kind of Dogwood (*Cornus*), or Asparagus Fern for a species of *Asparagus*.

Apart from grosser errors of the type alluded to above, popular names are often a source of confusion from the use of the same name for a variety of species. Bluebells may be Scillas or Campanulas, and Marigold may mean a species of *Calendula*, of *Tagetes*, or even a *Caltha*. So, too, we find that one kind of plant bears a number of different names. The Passion Flower of English gardens is the Maypop of Tennessee, and the woolly-leaved *Verbascum* may be designated by any of about a score of names from Hedge Torch and Mullein to Adam's Flannel and Candle-Wick. The name Candle-Wick is an excellent example of how an old name may enshrine the

history of the past, for this does not refer to the yellow spike of flowers, but to the ancient practice of using the fluff from the leaves, collected by penitents, for the making of the wicks of altar candles.

When we wish to refer to garden plants, the use of the Latin names which the botanist employs has several advantages, which it is well to realise, though, if regarded as mere labels, they are in no way superior to the English equivalents, and are often far less picturesque. Perhaps most important of all is the fact that there is only one valid Latin name for a particular kind of plant. It is true that sometimes botanists have described the same plant independently under different names, so that more than one has come into general use. Or, again, in a few instances botanists may not agree as to the genus into which a plant should be placed. One botanist will think the plant sufficiently like species of some existing genus to place it there, whilst another will consider it sufficiently distinct to warrant the creation of a new genus for its reception. For reasons such as these we find that one plant may bear several synonyms—as, for example, that early spring-flowering bulbous plant sometimes called the Missouri Lily, which has been variously known to botanists as *Allium uniflorum*, *Brodiea uniflora*, *Tritelia uniflora*, and *Milla uniflora*. Such multiplication of Latin names, however, is the exception, not the rule, and, though such synonyms are an inevitable accompaniment of advance in knowledge, only one Latin name is really valid for any one kind of plant, even though botanists may occasionally quarrel as to which the valid name is to be.

A second great advantage of the Latin name is that whereas we may have several popular names for the same plant in each of the languages where the plant grows wild, or is cultivated, the Latin name is common currency amongst all civilised peoples. So that one name serves as an international equivalent for, it may be twenty to fifty, popular names in a dozen different tongues.

If, further, we know something of botanical classification, the Latin name can tell us a great deal about the plant to which it is

applied. Each botanical name consists actually of three parts. The full name of the Madonna Lily, for example, is *Lilium candidum* L. The first name is the generic name, and is shared by all other true lilies; the second name is the specific name; whilst the letter L. stands for Linnaeus, who described the plant under this designation—in other words, it is the *Lilium candidum* of Linnaeus.

Sometimes the same binomial—as the generic and specific names are together called—has been used by different botanists for different plants. It is a convention that the earlier of these specific names only is valid, and another must be found for the plant named later, but the abbreviation of the authors' names after such 'homonyms,' as they are called, serve to distinguish between them. Not infrequently, however, in non-technical literature, and where there is little risk of confusion, the reference to the author of the species is omitted.

What, then, do we mean when we speak of a *species* of plant? A species is an aggregate of individuals all of which breed true to a smaller or larger number of characteristics, which they share in common. All the individuals are not exactly alike, for in addition to distinctions due to differing conditions of growth, which are not inherited, we include in the same species different *varieties*—as, for instance, the tall and dwarf varieties of the Sweet Pea (*Lathyrus odoratus*), and all the different true-breeding colour strains which both tall and dwarf varieties present.

How many hereditary distinctions a plant must possess to be regarded as belonging to a different species is a matter of opinion, and hence it is quite impossible rigidly to define a species. The species is, in fact, an aggregate of convenience in which we place plants that are similar, but not necessarily identical, in their hereditary qualities.

There are not lacking systematists who tend to make species which are aggregates not of convenience, but of inconvenience, by giving binomials to groups of plants that are either too large or too small.

The groups we call species are in turn collected into larger aggregates called *genera*. All the members of a genus resemble

one another more closely than they do the species of another genus. It is a convention, justified by experience, that the features upon which we rely for the distinction of genera are those of the reproductive organs—usually differences in the flower or fruit—whereas characters of the vegetative parts—as, for instance, habit and foliage—may be employed for the distinction of species.

Related genera are in turn grouped into *families*, and related families into *cohorts*. In all these larger groups, again, the characters of the reproductive organs are mainly utilised for diagnostic purposes.

The Carnation (*Dianthus Caryophyllus*), the Pink (*D. plumarius*), the Sweet William (*D. barbatus*), the Cheddar Pink (*D. caesius*) are all placed in the genus *Dianthus* together with nearly three hundred other species, including the unique yellow-flowered *Dianthus Knappii*. But all these three hundred species agree in having a pair of leaves just beneath the flower, in having a tube-like calyx without ribs where the sepals join by their edges, and in having two stigmas. All but the first of these features are also shared by the closely allied genus *Gypsophila*. The less closely allied genera *Silene* and *Lychnis* have a ribbed calyx, and from three to five stigmas. More remotely allied are the genera *Cerastium*, *Arenaria*, *Stellaria*, and nearly sixty other genera which are placed together in the family *Caryophyllaceae*, all the members of which have their leaves in pairs on the stem, which is usually swollen where the leaves join, and an inflorescence with an extremely regular type of branching. The fruit is characteristic, and, except in the genus *Paronychia* and a few others, contains a number of seeds borne on a placenta arising from the base, but generally free from the sides. There are a number of other features of less note, but, though some 1,300 species have been placed in this group, one can usually recognise the 'family likeness' at a glance.

A genus, like a species, is an aggregate of convenience, as we see from the fact that botanists are continually splitting up the larger genera into smaller as increase in knowledge adds species that render the genus unwieldy and reveals a basis for its division.

Still, though genera and species are groups of convenience, they are by no means as arbitrary as might at first appear, since it is soon found that the members of a genus grouped in the first instance on a relatively limited number of characters are subsequently found to share in common many others. Ultimately, by the utilisation of all the knowledge we possess regarding the external form and internal structure, even, it may be, the chemical nature of the plants concerned, we find that the members of our groups, even when very exceptional in respect to some one character, share a community of organisation which is often readily separable from the complex of characters shared by members of other groups.

Hence, though the basis of attainment may be somewhat conventional, and the size of our groups a matter of convenience, dictated by the state of our knowledge, yet we arrive at a system of classification that we believe represents an ever closer approximation to the real affinities between plants. Membership of a group, whether it be a species or a genus, is thus to be regarded as an indication of community of descent, but relationship between the species in one genus is not necessarily as close as that between the species of another.

As this is not a text-book, it is not proposed, even if space would permit, to outline the system of classification of plants, for which reference must be made to the special works on Taxonomy. All that need be emphasised here is the underlying principle that the system of classification, though continually requiring readjustment in the light of new knowledge, aims at an expression of all that we know concerning the resemblances and differences between organisms.

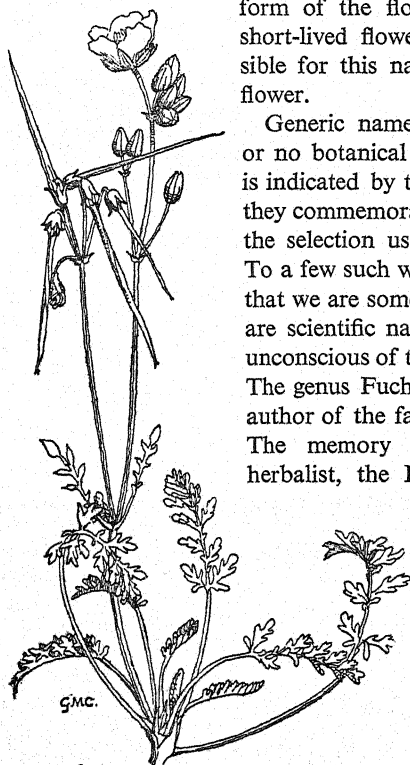
Once this principle is recognised, the Latin name of a species is apprehended as being something much more than a mere label. It implies a major share alike in the characters of the genus to which the plant belongs, and in those of the family of which the genus is a part.

Generic names may also indicate some characteristic feature of the genus—as, for example, *Erodium* and *Pelargonium*, derived respectively from the Greek words signifying a Heron and a

Stork, from the resemblance of the beaked fruits of these plants to the heads of those birds. *Streptocarpus* signifies the twisted fruits of that genus. *Gladiolus* means a little sword, and recalls the characteristic form of the foliage. *Oxalis* is from the Greek, meaning acid, and refers to the taste of the leaves. *Impatiens*, which is the generic name of the Balsam, recalls the bursting of the ripe fruits at a touch. *Cypripedium* signifies the Slipper of Venus, and the name *Calceolaria* also refers to the slipper-like shape of the lip of the flower. *Enkianthus* indicates the swollen form of the flowers of this shrub, and the short-lived flowers of *Piptanthus* are responsible for this name, which means the falling flower.

Generic names, however, often have little or no botanical significance in themselves, as is indicated by the fact that in many instances they commemorate the name of some botanist, the selection usually being entirely arbitrary. To a few such we have become so accustomed that we are sometimes scarcely aware that they are scientific names, and are almost certainly unconscious of their commemorative character. The genus *Fuchsia* recalls Leonard Fuchs, the author of the famous *Herbal* printed in 1543. The memory of another sixteenth-century herbalist, the Flemish botanist Matthias de

Lobel, is enshrined in the familiar *Lobelia*. The name of Dr. Dahl, who studied under Linnaeus, is perpetuated in *Dahlia*, whilst Linnaeus himself named the genus *Gunnera* after a certain bishop who was the author of a flora of Norway. Stephen Hales (1677-1761), the pioneer of plant physiology, is com-



Erodium Chrysantha

memorated in the genus *Halesia*. *Tradescantia* recalls the name of the gardener to Charles I. The popular annuals *Clarkia*, *Godetia*, *Bartonia*, and *Zinnia* all bear personal names. Captain Clark was a traveller in the Rocky Mountains with Captain Lewis, whose name is borne by *Lewisia*. Barton was a botanist of Philadelphia, and Zinn a Professor at Göttingen. Godet was a Swiss botanist. In the herbaceous border we have the commemorative names of *Monarda*, *Montbretia*, *Rudbeckia*, and *Paeonia*. Paeon was a physician; Monardes a sixteenth-century Spanish physician who travelled in the West Indies; Rudbeck a predecessor of Linnaeus in the Botanical Chair at Upsala. In the shrubbery, *Buddleia*, *Magnolia*, and *Robinia* recall the English botanist Buddle, the seventeenth-century Professor of Montpellier, Pierre Magnol, who was a pioneer in the natural classification of plants, and another French botanist Robin.

Specific names, also, may merely serve as distinguishing labels which commemorate collectors, botanists, and others—as, for example, *Berberis Wilsonae*, *Leptospermum Chapmani*, *Primula Wardii*, *Meconopsis Baileyi* (*M. betonicifolia*). More often they are indicative of some feature of the plant, such as its hairiness (*Rudbeckia hirta*, *Androsace lanuginosa*, *Calystegia pubescens*, *Cerastium tomentosum*), which suggest to us we can grow the plant in a dry situation. Sometimes the specific name is indicative of the habitat from which the plant was originally obtained. These may be very helpful, but they may also be misleading. We do not need a wood to grow *Dianthus sylvestris* or *Anemone sylvestris*; indeed, both will thrive in full sunshine.

Very frequently, however, the specific name reminds us of some characteristic feature of the plant, which serves to distinguish it from its close allies or is indicative of its provenance. One can perhaps best express the value of the scientific names by saying that it is not absolute, but relative. Only in relation to others do they attain their real significance, when the more we know the more they can mean to us.

It is just as easy to associate pink blossom and luscious fruit with the name *Pyrus malus* as with that of Apple. But, whereas the latter stands alone, the former brings with it visions of those

other species of *Pyrus* with which the Apple shares much in common, and of the resemblances to, and distinctions from, the many other cultivated genera of the *Rosaceae*; to which belong the Hawthorns, the Medlars, the Amelanchiers, the Quince, the *Cotoneasters*, the more remotely related Almonds, Cherries, Plums, *Kerria*, *Spiraeas*, Blackberries, *Rhodotypus*, and Roses, and a host of herbaceous perennials from the Dryas of our rock gardens to the Geums and *Potentillas* of our borders or the Strawberries of our fruit garden.

The Latin name of a strange flower may not, it is true, be any guide to its horticultural treatment, but it may tell us much concerning structure and life-history and so add not a little to our intelligent appreciation of the plants we tend.

The owners of gardens can often be grouped into those who know their plants but do not know their names, and those who know the names but do not know their plants. Of the two states of knowledge, the former is to be preferred, but there is fortunately an ever-increasing number of those who know their plants and know their names also, and for these the Latin binomials, with all their implications, can become, as it were, the links by which the framework of their knowledge is made whole.

CHAPTER XVII

THE SPAN OF LIFE

'Life can only be understood as an aim at that perfection which the conditions of its environment allow.'

A. N. WHITEHEAD. ADVENTURES OF IDEAS

I SUPPOSE most of us, laymen and botanists alike, if asked how long plants live would think instinctively of the old and familiar classification into annuals, biennials, and perennials. Yet these categories are in reality far more rough and ready than we might suppose. What, for instance, do we mean by an annual?

If we look in the *New English Dictionary* we shall find an annual plant defined as one 'existing or lasting for a year only,' and that is the sense in which most of us employ the description. But for a number of the plants we term annuals it is not strictly true, since many of them actually live longer than a year. The self-sown *Calendulas*, for instance, that come up in the early autumn may survive for fourteen or fifteen months.

What is of more practical importance is the distinction between 'winter annuals,' which normally germinate in the autumn of one year and flower in the summer of the next—as, for example, *Love-in-the-Mist* (*Nigella*)—and the summer annuals, which germinate in the spring or summer, and so escape the rigours of winter.

If we do not sow winter annuals till the spring, they have a shorter period of growth, make smaller plants, and bloom later. Autumn-sown *Larkspurs*, *Love-in-the-Mist*, and *Cornflowers* may bloom three weeks to a month earlier than the same varieties sown in spring. If we sow the summer annuals in the autumn, they will probably not germinate, or, if they do, we shall be lucky if any survive to the flowering season.

The summer annual has naturally a very short span of life which may, like some of the weeds referred to in an earlier

chapter, complete its whole life cycle, from germination to the shedding of its seeds, in the space of a few weeks.

If we consistently remove the flower buds from an annual such as, for example, a Mignonette, the plant can be induced to survive for several years. This suggests that the expenditure of the plant's resources in flower and fruit production has something to do with its death. One way in which this might come about is that the amount of sugars remaining in the plant might be too small to protect the proteins from coagulation by frost. But, whatever the precise mechanism, it is reasonable to assume that the vigour of the plant is diminished by reproduction so as to render it in one way or another more susceptible to adverse climatic conditions, or perhaps to attack by fungi and insects; (sometimes, however, it is the more vigorous plants that are the more susceptible to such pests).

Owing to the large amount of energy and material expended in seed formation and fruit development, we can understand that the continual cutting off of the flowers before the fruit develops will prolong the flowering period or, as in *Delphiniums*, lead to a second blooming. Such repeated flowering may, however, in the end, result in a greater drain upon the vigour of the plant than if it were allowed to produce seed.

The biennials such as the Carrots, Beetroots, Parsnips, etc., that we raise from seed in the spring, occupy the first year in hoarding up their savings to be spent the following season, if we leave them in the soil, in the production of flowers and fruit. Such plants clearly differ only from our autumn-sown annuals in spending a rather longer period in preparation for reproduction. If we sow Onions, Beetroots, or Cabbages too early in the year, and they receive a sudden check by a late frost, they are liable to 'bolt'—that is to say, to flower and fruit in their first season. A check to growth, caused by drought, may have the same effect, and this suggests that under normal conditions it may be the unfavourable influence of the winter season which leads to flower production in the second summer.

The similarity in behaviour of the winter annual and the biennial has led botanists to distinguish between those plants

which normally fruit once only and those that fruit repeatedly. The former, or 'monocarpic,' type would, of course, include all those plants we class as annuals and biennials, together with certain perennials, of which latter the Talipot Palm of Ceylon is a classical example. This tree lives for a number of years in a completely vegetative condition, and then produces a great mass of flowers and dies. Actually the span of life in this instance is approximately half a century. The so-called Century Plant of Mexico (*Agave americana*) also only flowers once, but the period of preparation during which it accumulates food material may be as short as five years or as long as a hundred, with a corresponding variation in length of life, unless suckers are formed.

Even more striking is the behaviour of the South American *Furcraea longaeve*, which has a long life, though not a gay one, lasting, it is asserted, for from four hundred to five hundred years before it ends in a burst of glory with an inflorescence thirty feet in height and branches twelve to fifteen feet long.

All the different types of monocarpic plants are apt to show varying lengths of life depending upon when they flower. The biennial *Meconopsis Wallichii* will not infrequently flower in the third instead of the second year. We can, as already noted, artificially prolong the vegetative period of the annual by checking flower production. In this way it is possible to grow annuals as biennials and biennials as triennials, with a corresponding increase in their size and capacity for flowering. A biennial *Schizanthus* may attain more than twice the height of its annual counterpart, and disbudded Mignonette plants have been known to attain a tree-like form and a height of over six feet.

Just as the monocarpic perennials may be said to behave like annuals with respect to their flowering, so, too, some perennials may be said to resemble annuals in their vegetative growth. For instance, the perennial Sunflower (*Helianthus*) is in a sense only perennial by courtesy. No part of the plant actually lives for more than a year. The swollen underground side shoots, like those of its relative the Jerusalem Artichoke, grow upwards into leafy shoots, which perish with them at the end of the autumn,

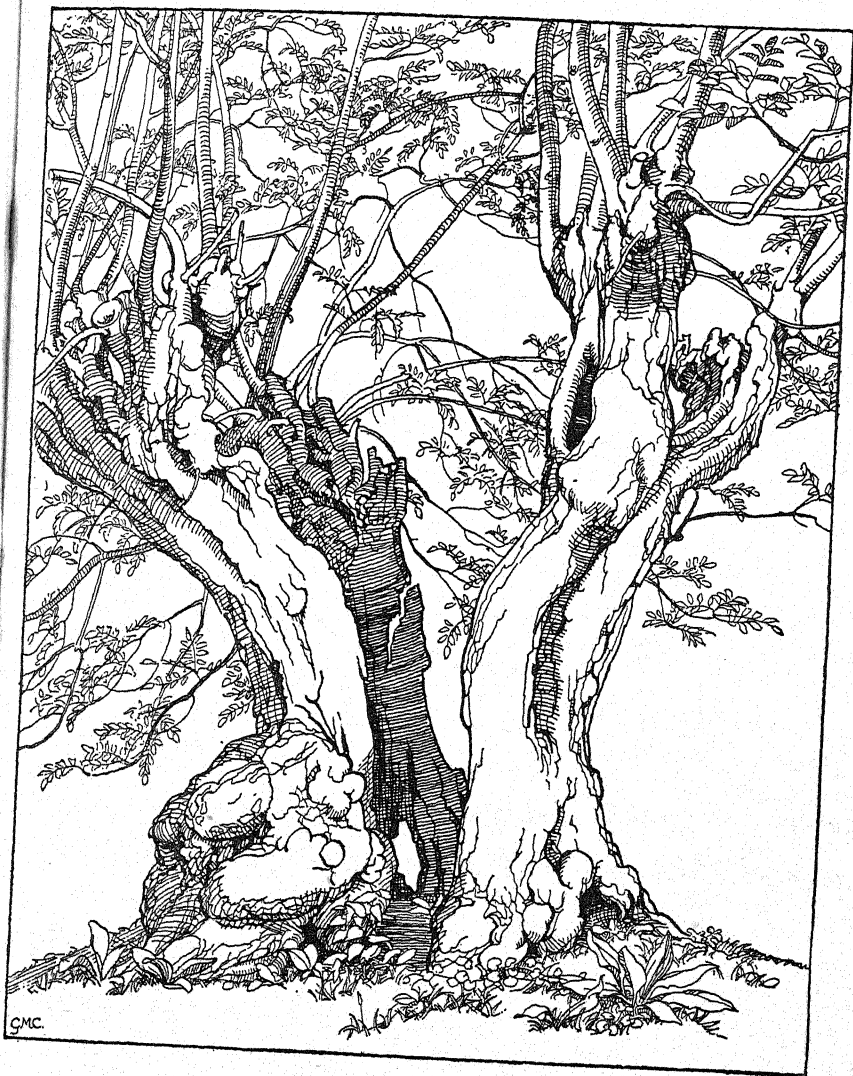
and only the newly formed shoots beneath the soil persist, to grow up in their turn and perish.

This method of perennation by side shoots is brought vividly before us when we cultivate the Blue Himalayan Poppy (*Meconopsis betonicifolia*). Is this an annual or a perennial? The answer we give, based on our own experience, will depend on whether or no, under the conditions of culture we give it, offsets are produced from the base of the flowering stem, since it is by virtue of these alone that the plant persists from year to year.

The length of life of the plant as a whole, or of its parts, has not only a practical importance for the horticulturist, but is of considerable interest for our understanding of plant life. Unfortunately our knowledge of the span of life and its causes is very meagre, and those who possess gardens could do much to increase our data as to the duration of individuals, both of different species and of the same species, under diverse conditions of growth.

Most people when they speak of a perennial think of a plant that persists more or less indefinitely, yet actually the length of life of the plants we call perennial is most varied. Yew-trees, although their ages are often greatly exaggerated, can probably attain to well over 500 years. There is good evidence to indicate that the Giant Sequoias of California attain to at least two thousand years, and it has been suggested that some may live for between four thousand and five thousand years. An Oak-tree may reach an age of perhaps 1,500 years, but Poplars and Horn-beams probably do not normally live for more than two centuries unless pollarded.

It should be remembered that, even in the most patriarchal trees, it is but a proportion of the entire structure which remains alive. The trunk and branches are progressively dying from within outwards each year, whilst new tissues are added nearer the surface. This is vividly exemplified by ancient trees that still appear quite vigorous despite a completely hollow trunk. So that the actual length of life of any particular part of the tree is much less than its actual age as a whole. The Scotch Pine, although it will attain to an age of about 250 years, does not



The Hollow Ash

apparently contain any cells that retain their vitality for more than about eighty years, and usually the oldest remaining alive have not functioned for much over a quarter of a century. Living cells, and the tissues they constitute, are continually dying, and as continually being replaced by others newly formed. How soon the dead tissues decay varies both with the nature of the plant and upon accidents of infection by fungi and bacteria.

Why the tree should eventually die is a matter for conjecture, though one may suppose that the increasing surface in relation to the volume of living tissue, and the increased difficulties of transport which increase of size brings with it, may play their part in the process of increasing senility. This suggestion gains support from the greater length of life of pollarded trees as compared with unpruned specimens, provided the pruning has not brought about fungal infection. So, too, repeated trimming seems to produce a rejuvenating effect.

In the tree it is the persistence of the older non-living parts which enables the superficial living tissues to remain joined together, and we speak of the entire structure, composed of both the living substance and the dead, as an ancient tree.

In one sense, a long-established variety of garden Potato might also be spoken of as an ancient individual, since all the tubers that are planted to-day are but the youngest surviving parts of an individual that we can trace back to the time when the variety originated, although the material connections have perished and the living parts have been separated in space.

The seedless Banana would seem to show no loss of vitality from its prolonged vegetative multiplication, so that there does not appear to be any intrinsic reason why a plant should not be potentially immortal if, as when we reproduce by cuttings, we continually check the tendency towards increase of size with increase of age.

An individual Carnation is usually old and decrepit if we allow it to grow for six or seven years, though it may not survive so long. Yet we can prolong its life apparently indefinitely by repeatedly taking cuttings. This is a feature so familiar that

we rarely pause to consider its significance, but its practical application is utilised in the culture of a Lavender hedge, which, if carefully and repeatedly trimmed, will persist, whereas the unpruned Lavender bush is comparatively short-lived.

Except for some trees and shrubs of which we have records, our estimates of the length of life of plants are largely speculative, particularly with regard to herbaceous perennials. The horticulturist, if he takes thought for the death of a plant that has survived some years, will probably attribute the loss to the accidents of our climate, or his own inefficiency in its culture. This may be the 'last straw,' but rarely does it occur to him that the plant was mainly suffering from old age.

We all know that the old-fashioned Wallflower, like its wild progenitor, was a perennial that lived for several years at least, but many modern varieties are annuals or biennials. This is clearly not due merely to exhaustion through flowering, since, though the blooms of the newer varieties are larger, the wild plants are often much more floriferous. This is true also of the wild Cabbages that grow, for example, on the rocks of the Glamorgan coast. These are true perennials, and one large specimen that I examined bore over five thousand pods, with an average of fourteen apparently good seeds in each—a potential progeny of over seventy thousand! Nevertheless the cultivated descendants of the wild Cabbage are biennials, indicating some hereditary constitutional difference. But in what does this hereditary difference lie?

Cultural conditions do naturally influence the length of life, as we find is the case when growing *Eschscholzas*. Many gardeners regard these plants as annuals, but on dry sandy soils they may live for several years and attain to a large size.

The wild Sweet William (*Dianthus barbatus*) is a perennial species, but some garden varieties are winter annuals or biennials. The fact that some species of *Dianthus* are referred to in works on gardening as dying 'for no apparent reason' is sufficient indication that the short span of life of some perennials is not realised as a natural characteristic. Many horticulturists assume that if a plant is not actually an annual or biennial it may be

regarded as continuing indefinitely. Yet the length of life of such species as *Dianthus superbis* and *Daphne cneorum* is relatively short, though subject to some variation according to the conditions of culture.

If we could obtain careful records of the exact span of life of individuals, grown under different conditions, of a number of our commonly cultivated species, it would be of great practical interest, and would probably help in no small degree towards our understanding of the significance of this important aspect of plant life.

POSTSCRIPT

'Progress is marked not so much by the problems we are able to solve as by the questions we are enabled to ask.'

A. S. EDDINGTON. ADDRESS AT UNIVERSITY COLLEGE, LONDON

WE HAVE in these pages taken together a journey of the mind through our gardens and seen something of the pageant of the seasons and the vicissitudes of the individual plants as part of a never-ceasing adjustment both to the conditions that nature provides and those that we ourselves impose.

If we have rightly apprehended the plants we tend, as living organisms, we cannot fail to find the processes of nature as significant and fascinating as the results which they achieve. To the constant changes both internal and external we see continual reaction throughout life, from the seedling to maturity, and the more we know of these the better adepts we become in the horticultural craft, and the greater our pleasure in its pursuit.

Though our gardens may suffer from the vagaries of our climate, neither wind nor rain, frost nor drought, can leave us entirely bereft of compensation through the enlargement of our vision of the living plant in its adjustment to the environment.

We shall learn alike from our failures and our successes. The winter's rest will have its appeal no less sublime than the quickening promise of spring, the rich fulfilment of summer, or the transitory charm of autumn.

We shall learn also to appreciate something of the unity which links the garden of our making with the wild garden of the world around; for the more we prize and understand our gardens, the more we shall appreciate and treasure the beauties of nature uncontrolled. Each supplements the other and to understand either we must contemplate both.

The eye is but the implement for comprehension by the mind. Sight must by knowledge be quickened to insight, the birth of

vision. Inherited defects we shall then perhaps apprehend as the heritage of past perfections that have become an incubus to adaptation for present needs, but to savour the full beauty of the living world demands a perfection of human understanding.

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